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Patrick H. Walker
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Postglacial Environments in Relation to Landscape and Soils on the Cary Drift, Iowa

by Patrick H. Walker

Department of Agronomy

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PREFACE

For the past 15 years coordinated studies in geomorphology and soils have been directed toward trying to determine what effect the processes of evolution of the landscape have on the formation of soils on that landscape. Somehow, during the previous studies, certain pertinent aspects (e.g., environmental factors through time) have eluded the investigators.

In the following report Patrick Walker integrates a research approach using the sciences of stratigraphy, geochronology, palynology, sedimentology, geomorphology and paleobotany with a liberal use of analysis through mathematics. All are directed toward explaining the nature and history of the soils on the landscape in question. In the current state of the art, this approach is somewhat unusual. Certainly the results are encouraging.

This report should be of general interest to earth scientists and of specific interest to pedologists. Because many different fields of science are used to tell the story, one should expect to have to study this publication and, perhaps, background literature as well. The effort will be well worth the time.

Robert V. Ruhe
Professor of Soils
Department of Agronomy
Iowa State University

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SUMMARY

The objectives of this study were to evaluate environmental and time factors in the genesis of soils and soil landscapes on the Cary drift in Iowa, with special reference to soils of the Clarion toposequence.

The stratigraphy of five bogs along the Des Moines lobe was studied in detail; and as a result, a general bog stratigraphy was established for the Cary drift in Iowa. The stratigraphic zones and appropriate radiocarbon dates are as follows: upper muck zone (UM), 0-3,000 years; upper silt zone (US), 3,000-8,000 years; lower muck zone (LM), 8,000-10,500 years; lower silt zone (LS), 10,500-13,000 years; Cary sediments, >13,000 years. Pollen and macrofossil data indicated that forest vegetation was prominent on the landscape until 8,000 years ago; and subsequently, herbaceous prairie flora dominated the landscape up to the time of settlement. Erosional rates for hillslopes and depositional rates for bog areas were calculated for each of the stratigraphic zones given. The muck zones represent relatively slow hillslope erosion and a preferential accumulation of organic matter in the bog; the silt zones represent relatively rapid erosion and a preferential mineral sedimentation in the bog. Hillslope erosion 8,000 to 3,000 years ago was the greatest of all the intervals and removed an average of 1.7 feet of soil from the upper slopes of the Colo bog watershed and 5.3 feet from the upper slopes of the Jewell watershed. The extent of erosion and deposition during this interval insures that most soils of the Colo and Jewell watersheds developed on relatively young surfaces under prairie vegetation. Many soils of the Webster, Harpster and Glencoe series developed the upper part of their solum in surficial sediment rather than the drift, and their profile properties relate to the last 3,000 years of prairie environment.

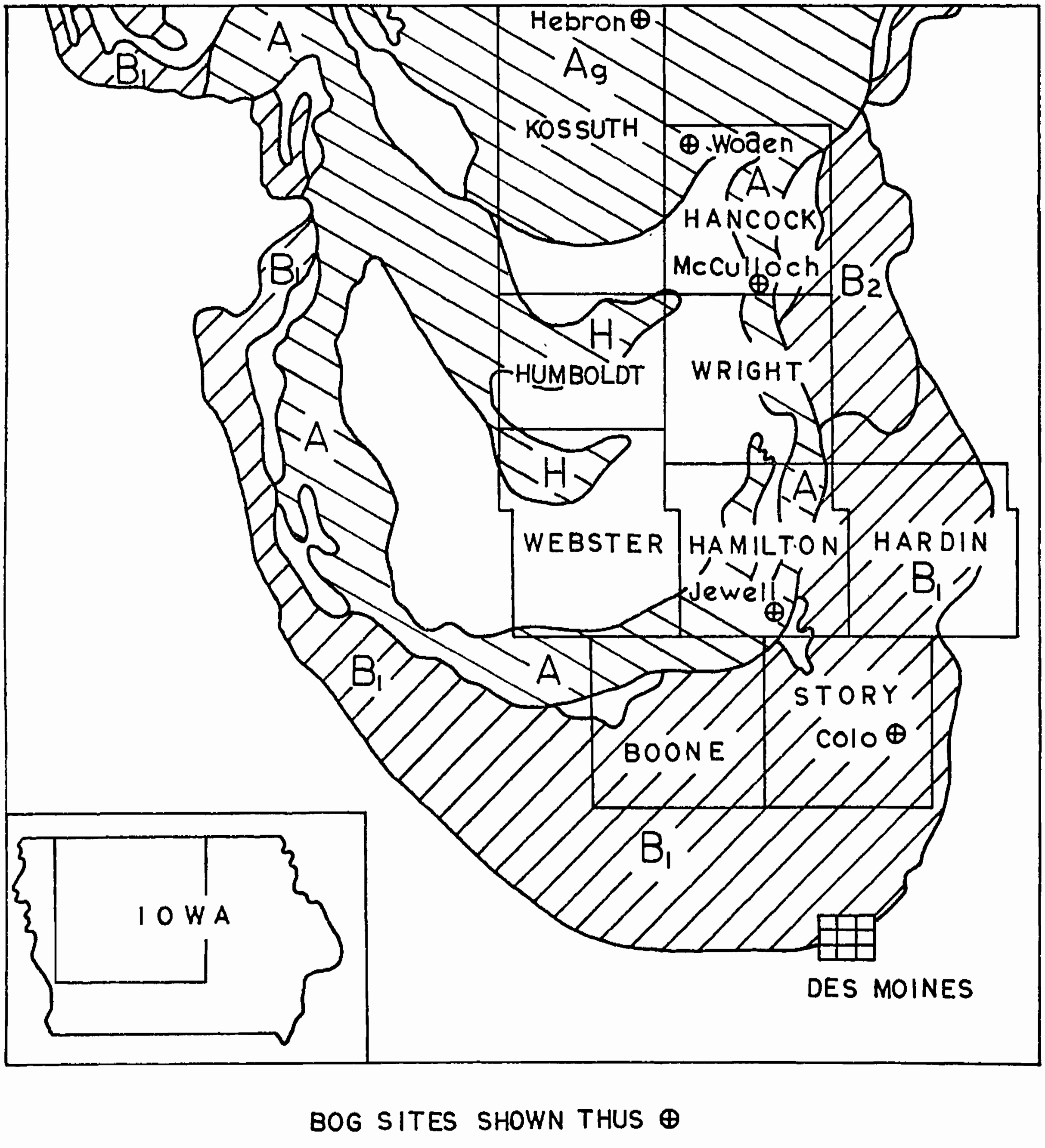


Figure 1. Map of the Des Moines lobe in Iowa, after Ruhe (1952), showing bog locations and the four morainal systems. B1, B2 = Bemis; A = Altamont; H = Humboldt; Ag = Algona.

Postglacial Environments in Relation to Landscape and Soils on the Cary Drift, Iowa[1]

by Patrick H. Walker[2]

The work reported here is part of a program aimed at evaluating the effect of climatic, vegetational and time factors on the landscapes and soils of Iowa. In this bulletin, the discussion is confined almost entirely to the Clarion, Nicollet and Webster soils and associated landscapes of the Cary drift.

The Des Moines lobe of the Cary drift (fig. 1) is the youngest glacial deposit in Iowa. Radiocarbon dates published by Ruhe and Scholtes (1959) indicate that glaciation in Iowa terminated 13,000 years ago. Further dates on alluvial fill on the Cary drift and in adjacent landscapes (Ruhe et al. 1957; Ruhe and Daniels 1965) suggest that the postglacial environment in Iowa did not ameliorate steadily. Rather, the environment fluctuated to produce erosional conditions on the landscape. Some indication of the magnitude of reduction in relief of the drift landscape because of erosion is given by Wallace (1961), who reported as much as 20 feet of fine sediment in depressions.

Lane (1931) published the first postglacial pollen diagram in Iowa for the McCulloch bog (fig. 1). Conifers dominated the pollen spectrum in the lower part of the postglacial sediments, and these were replaced by species such as oak in the middle part of the profile. The upper part of the profile, including the surface, was dominated by herbaceous pollens. Radiocarbon dates by Ruhe et al. (1957) of 11,660 ± 250 and 11,790 ± 250 years for the base of the McCulloch bog, 8,110 ± 200 and 8,170 ± 200 years for the top of the conifer zone, and 6,570 ± 200 and 6,580 ± 200 years for the transition to the herbaceous zone of the pollen profile, tend to confirm Lane's view that forest species were established on the Cary drift surface during early postglacial time. McComb and Loomis (1944) concluded from studies of the prairie-forest transition of central Iowa that a late change in postglacial climate from relatively dry prairie to more mesic conditions has led to an encroachment of oak-hickory forest onto the prairie. This suggestion of a late advance of forest is supported by trends recently established in pollen profiles of southern Minnesota by Wright et al. (1963).

This evidence of waxing and waning forest influence in central Iowa raises a question as to the status of the Clarion, Nicollet and Webster soils, considered to have been formed under prairie vegetation (Oschwald et al. 1965, p. 28-30). The objective here is to establish a historical framework of vegetation and landscape in relation to these soils. Within such a framework, the genetic pathway of soil development can be determined.

Areas of Study

The Cary drift surface is characterized by poorly integrated drainage in which small enclosed basins and peat bogs occur. These bogs have collected materials relative to vegetational and sedimentational episodes of the past and offer the best opportunity for reconstructing landscape history. In an earlier phase of this project, a reconnaissance of deeper bogs on the Cary drift surface was reported by Walker and Brush (1963) and revealed the general occurrence of double mineral and double organic strata. Subsequently, five bog watersheds were chosen for detailed study; these lie along the north-south axis of the Des Moines lobe and represent the range of morainal topographies described by Ruhe (1952). The general locations of these watersheds are shown in fig. 1, and details of location are given in table 1. The McCulloch bog of this paper is the East McCulloch bog described by Lane (1931) and Ruhe et al. (1957). The other four bogs have not been previously investigated.

Table 1. Location descriptions of five bogs studied on the Cary drift.

Bog	Location	Moraine
Colo	Sec. 10, 11, T. 83 N., R. 21 W., Story County, Iowa	Bemis
Jewell	Sec. 13, 24, T. 86 N., R. 25 W., and sec. 18, 19, T. 86 N., R. 24 W., Hamilton County, Iowa	Altamont
McCulloch	Sec. 32, T. 94 N., R. 24 W., Hancock County, Iowa	Altamont
Woden	Sec. 13, T. 97 N., R. 26 W., Hancock County, Iowa	Algona
Hebron	Sec. 27, T. 100 N., R. 27 W., Kossuth County, Iowa	Algona

[1] Project 1250, Iowa Agricultural and Home Economics Experiment Station. This paper is based on the dissertation submitted by P. H. Walker to the graduate faculty of Iowa State University in partial fulfillment of the requirements for the degree of doctor of philosophy, under the direction of R. V. Ruhe. The research was part of a project under National Science Foundation Grant GP2610, directed by F. F. Riecken and W. H. Scholtes.

[2] Formerly research associate, Department of Agronomy, Iowa State University. Present address: Division of Soils, Commonwealth Scientific and Industrial Research Organization, Canberra, Australia.

Topographic surveys based on local datum level were carried out in the Colo and Jewell watersheds where the work was most detailed. The contour maps of the watersheds are shown in figs. 2 and 3. Both Colo and Jewell bogs have the topographic features of closure necessary for storage of the postglacial sedimentary and vegetative record. North of the Jewell watershed, however, there are several topographic features higher than the perimeter shown in fig. 3. These may have contributed a minor amount of sediment to the bog in the past, but their connection to the delineated watershed is at present indirect; hence, these topographic high points are omitted from further discussion. Detailed topographic data were not obtained for the other three bog watersheds.

Bog Stratigraphy

Colo Bog

The stratigraphy at the center of the Colo bog is best illustrated by reference to profile C22 (see fig. 2b).[3]

Profile description of Colo bog center profile C22: Location: 278 feet W., 13 feet N. of SE cor. SW¼ NW¼ sec. 11, T. 83 N., R. 21 W., Story County, Iowa.

[3] The descriptions follow the soil nomenclature of the U. S. Soil Survey Staff (1960), and the Munsell notation is given for moist color. The buried-horizon nomenclature of Ruhe and Daniels (1958) is used.

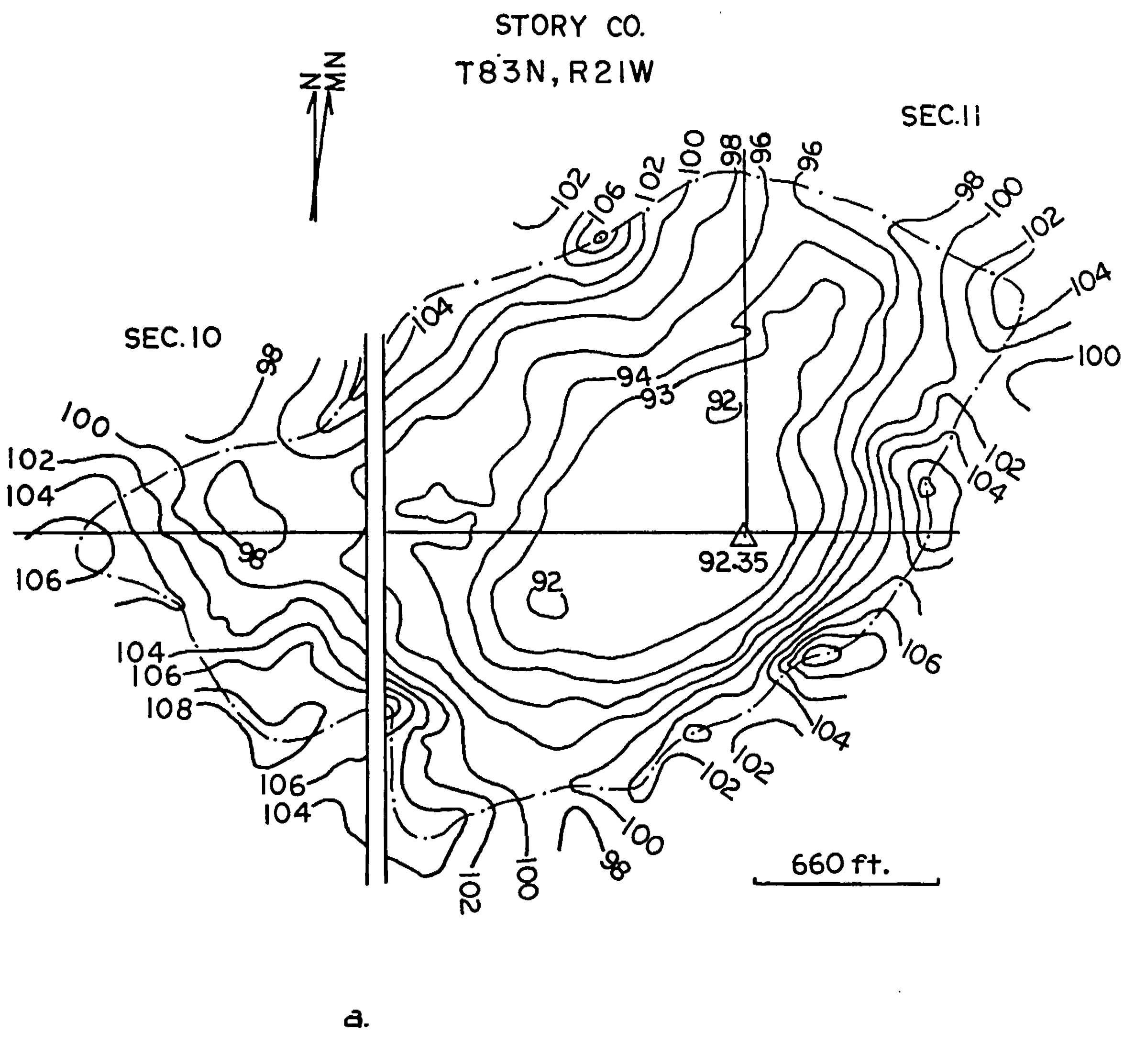
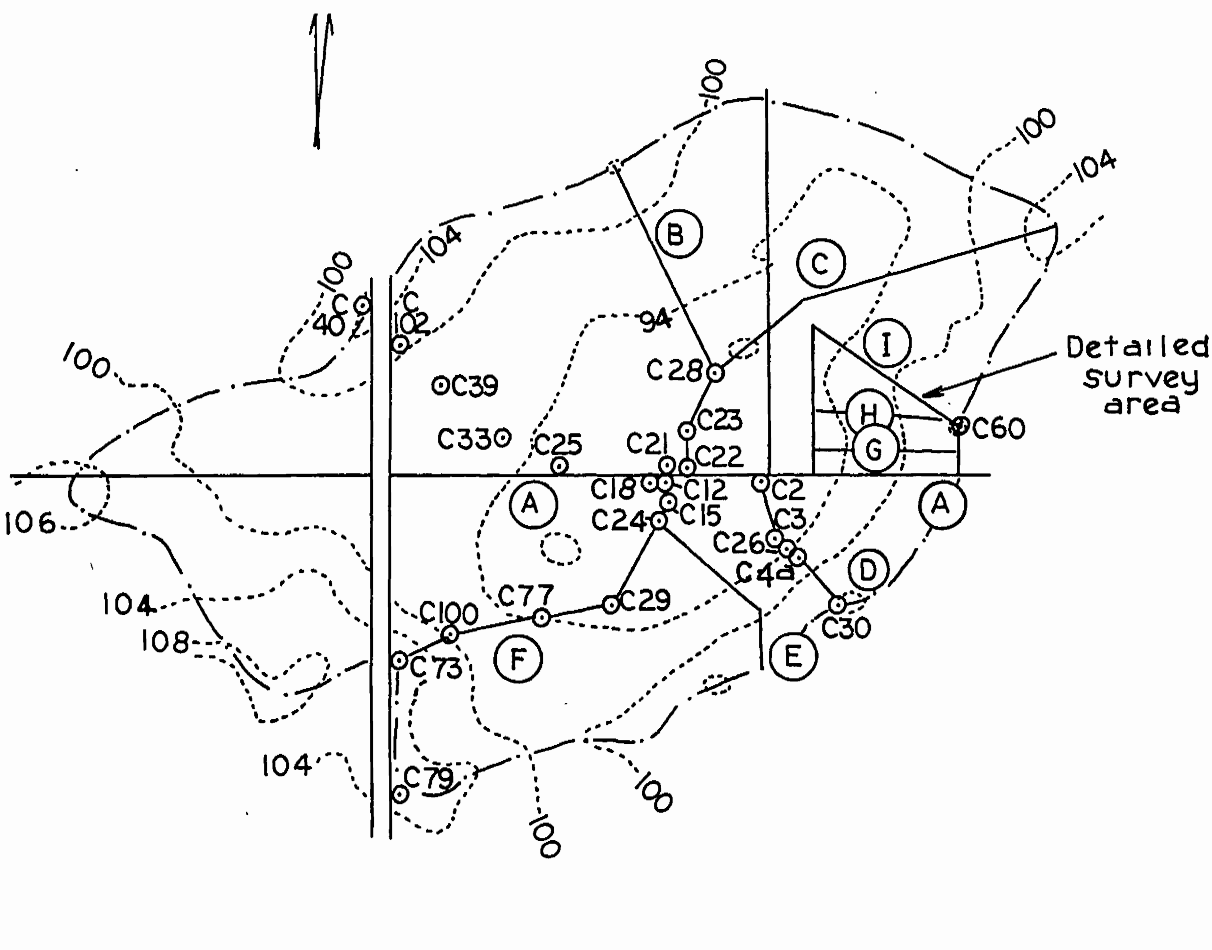


Figure 2a. Topographic map of the Colo bog watershed, based on a local datum of 92.35 feet.

Horizon	*Depth (inches)*	*Description*
Upper muck (UM)		
O2	0-9	N 2/0, muck, slightly sticky, slightly plastic, abundant modern roots, noncalcareous, clear boundary.
O1	9-32	5YR 2/1, 10YR 2/2, mottled, peat, nonsticky, nonplastic, noncalcareous, gradual boundary.
Upper silt (US)		
C1	32-38	10YR 2/1, mucky clay loam, sticky, slightly plastic, weakly calcareous, occasional shells, gradual boundary.
C2	38-52	10YR 2/1, mucky clay, sticky, plastic, shells common, diffuse boundary.
C3	52-89	10YR 2/1, silty clay, sticky, plastic, occasional shells, abrupt boundary.
C4	89-90	5Y 6/2, silt loam, slightly sticky, slightly plastic, occasional shells, calcareous, abrupt boundary.
C5	90-120	10YR 2/1, silty clay loam, sticky, plastic, occasional shells, calcareous, diffuse boundary.
Lower muck (LM)		
O21b	120-134	10YR 2/1, peaty muck, sticky, slightly plastic, occasional shells, weakly calcareous, diffuse boundary.
O22b	134-154	5Y 2/1, peaty muck, sticky, slightly plastic, no shells, noncalcareous, 1-inch piece of spruce wood at 135 inches, diffuse boundary.
O23b	154-177	5Y 2/1, muck, sticky, slightly plastic, no shells, noncalcareous, abrupt boundary.
O24b	177-179	5Y 4/3, muck, sticky, slightly plastic, no shells, calcareous, abrupt boundary.



b.

Figure 2b. Map of sampled profiles and transects.

O25b	179-189	5Y 2/1, muck, sticky, slightly plastic, no shells, noncalcareous, diffuse boundary.

Lower silt (LS)

C1b	189-206	5Y 3/2, silty clay loam, sticky, plastic, noncalcareous, gradual boundary.
C2b	206-209	5Y 2/1, silty clay loam, sticky, plastic, occasional shells, calcareous, abrupt boundary.
C3b	209-216	5Y 4/1, silt loam, sticky, plastic, no shells, calcareous, abrupt boundary.
C4b	216-221	10YR 2/1, silt loam, sticky, slightly plastic, occasional shells, calcareous, abrupt boundary.
C5b	221-230	5Y 4/1, silt loam, sticky, slightly plastic, occasional shells, calcareous, clear boundary.
C6b	230-240	5GY 4/1, silty clay loam, sticky, plastic, calcareous, clear boundary.

Till

	240-246	5Y 5/1, loam, with gravelly component, calcareous, gradual boundary.
	246-276	5Y 4-5/1, loam, with gravelly component, calcareous.

In this and subsequent descriptions, an informal designation is used to differentiate essentially organic materials, such as muck and peat, from essentially mineral sediments, such as silt loams, loams, etc. On the basis of this designation and their rela-

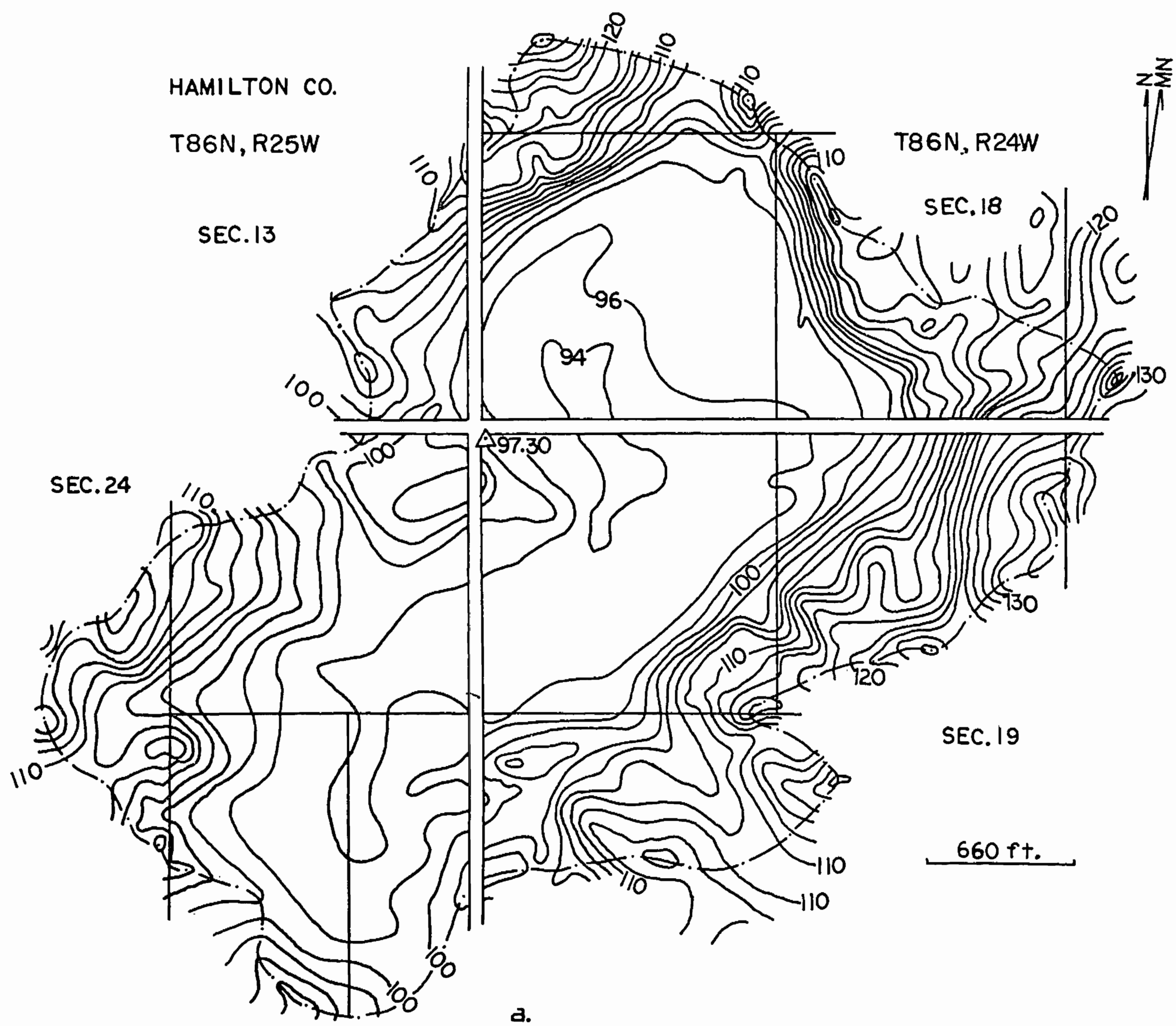


Figure 3a. Topographic map of the Jewell bog watershed, based on a local datum of 97.30 feet.

tive stratigraphic position, four bog zones were defined in Colo profile C22: the upper muck zone (UM) from 0 to 32 inches, the upper silt zone (US) from 32 to 120 inches, the lower muck zone (LM) from 120 to 189 inches and the lower silt zone (LS) from 189 to 240 inches. The term silt is used in a lithologic, stratigraphic sense and is not restricted to a textural class. Below the bog sediments are the Cary drift sediments. A three-dimensional picture of the bog zones at the Colo site is shown in fig. 4, constructed from traverse data. The proportion of the watershed underlain by UM/US/LM/LS sediments is small. The LM zone, in particular, wedges out quickly in all directions, whereas the other zones extend to the foot of the adjacent hillsides. The nature of all bog-zone materials changes with distance from the bog center. As the LM zone thins, it becomes more intensely laminated and its consistency toughens. The UM zone tends to become thinner toward the edge of the bog and eventually becomes interstratified with sandy hillside surficial sediment. Both US and LS zones become thinner away from the bog center; the former interfingers with hillside surficial sediment, and the latter becomes interstratified with iron-impregnated sandy and gravelly sediments set into the drift toeslopes. The coarse sediments are designated toeslope sands (TS, dotted pattern fig. 4).

The relationship between bog and hillside sediments is shown in detail for five sections on the east side of the Colo Bog watershed in fig. 5. Three important features of these sections are noted here. First, the occurrence of a stone line, as defined by Ruhe (1956, 1959), indicates an erosional origin of most of the surficial materials on the sideslopes in the watershed. The stone line thickens downslope and interfingers with the US zone sediments, thus establishing

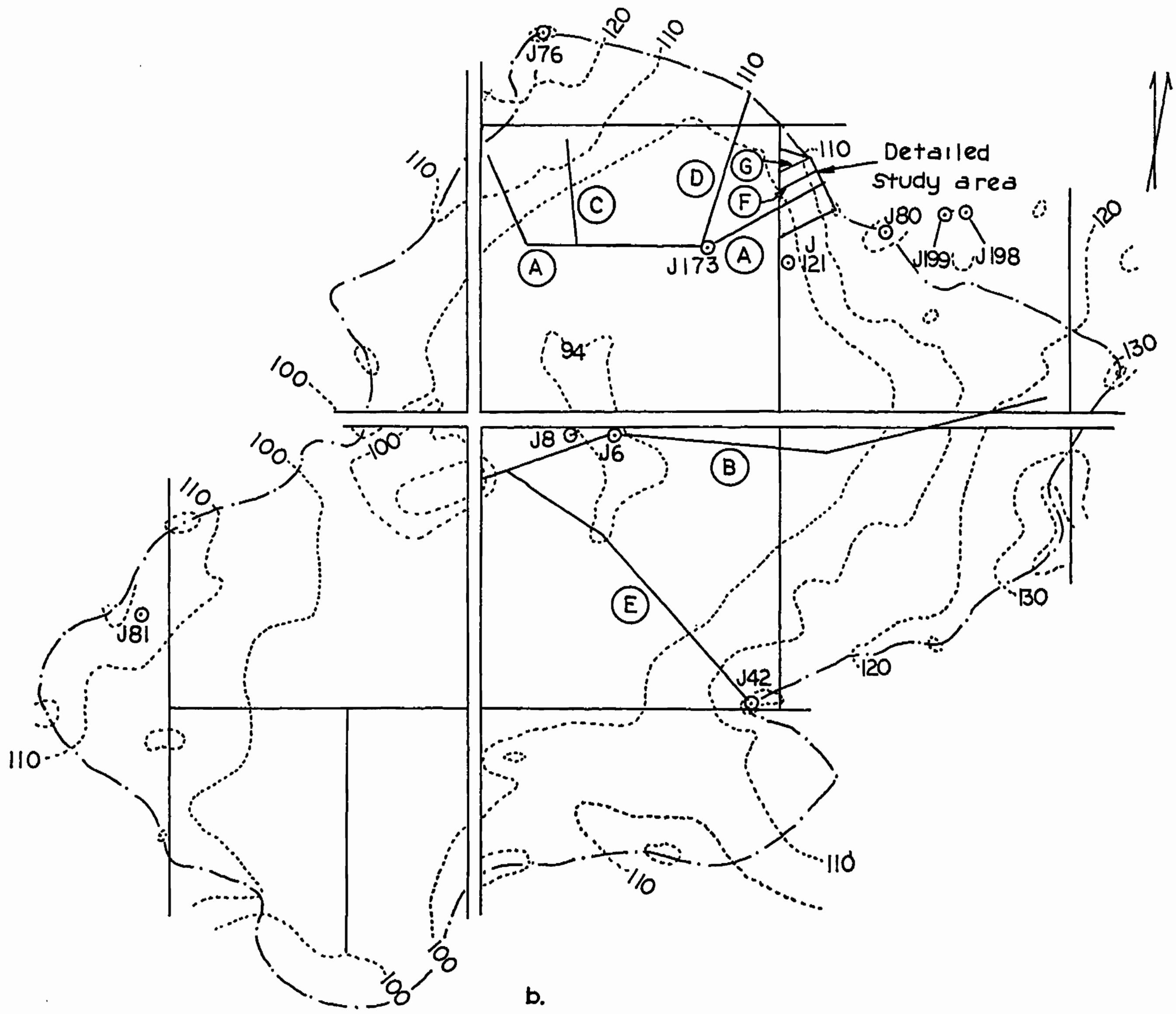


Figure 3b. Map of sampled profiles and transects.

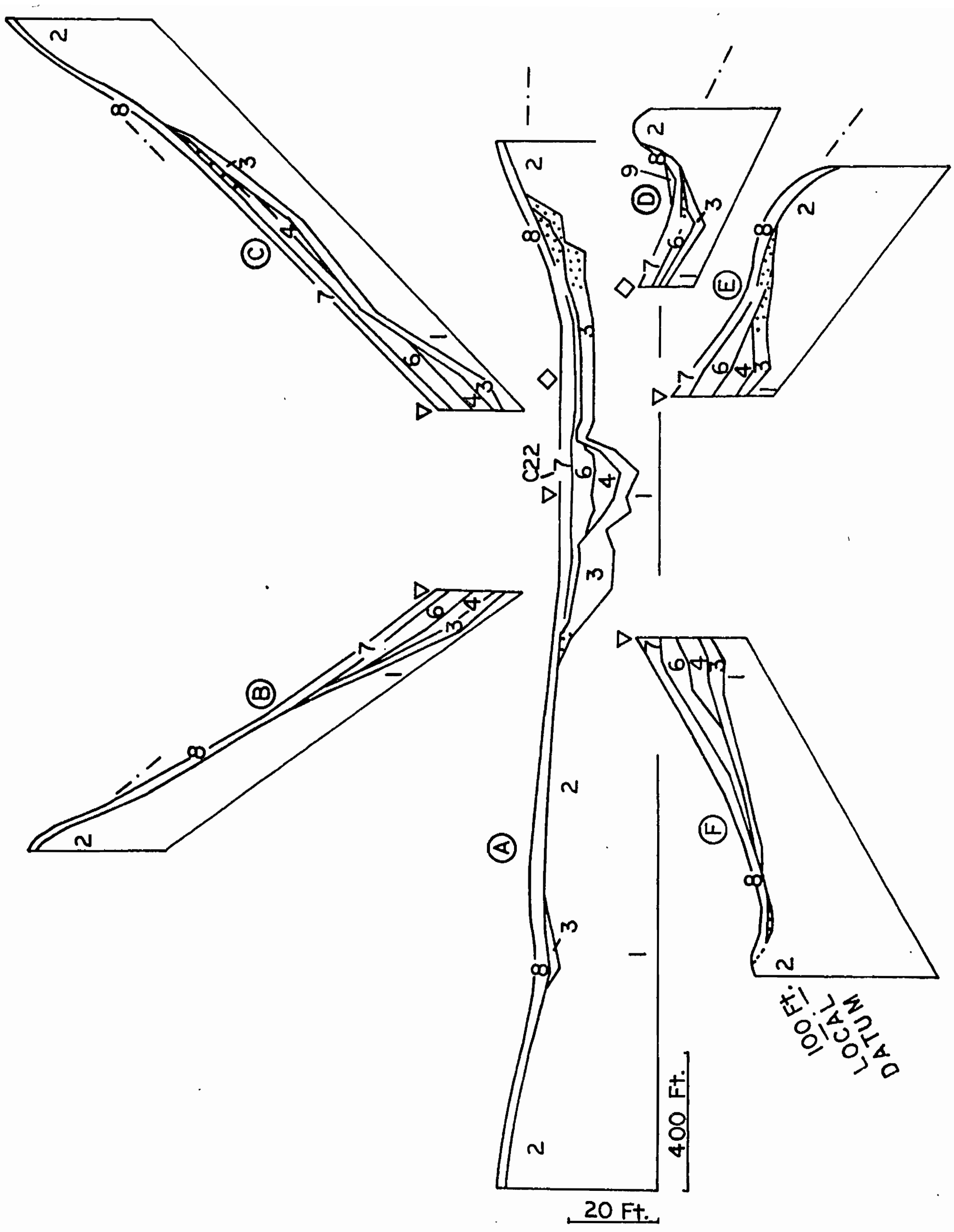


Figure 4. Radial sections showing the stratigraphy of the Colo bog watershed: unoxidized and unleached Cary drift (1); oxidized and unleached Cary drift (2); lower silt zone (3); lower muck zone (4); upper silt zone (6); upper muck zone (7); hillside surficials (8); postsettlement deposits (9).

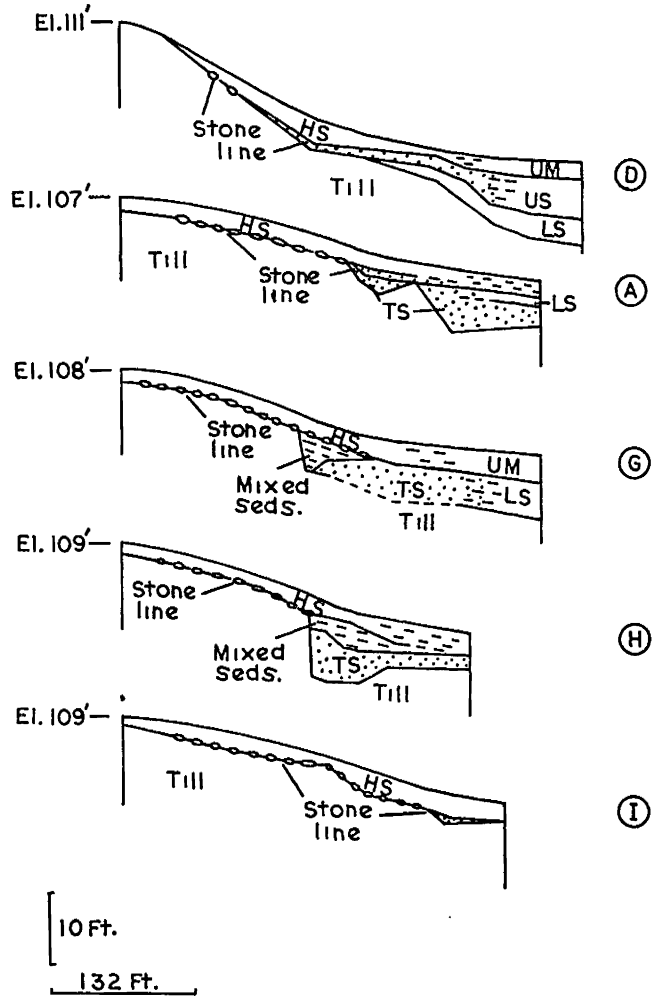


Figure 5. Transects across the east side of the Colo bog watershed, showing hillside and bog stratigraphy. HS is hillslope surficial sediment.

the stratigraphic identity of the hillside surficial sediment and the upper part of the US bog sediments. A second notable feature of these sections is the occurrence of the uppermost sediment of the toeslope sands at 96 feet (local datum), suggesting a lacustrine influence in the deposition of these coarse sediments. This is further confirmed by the general occurrence of these sands in concave rather than convex positions along slope contours. The third feature is that the landscape is smoothed from the hillsides into the bog environment. This is consistent with the gradual transition from mineral sediment on the hillsides to organic materials in the bog UM zone and indicates that the latest increments of deposition in the bog have been adjusted to the latest decrements of hillside erosion. Such features point to the continuity of the one geomorphic surface from hillside to bog center.

Jewell Bog

Two bog profiles, J6 and J173, were sampled for detailed study at Jewell (fig. 3). Profile J173 is described.

Profile description of Jewell bog profile J173:
Location: 740 feet N., 317 feet W. of the SE cor. SW¼ SW¼ sec. 18, T.86 N., R.24 W., Hamilton County, Iowa.

Horizon	*Depth (inches)*	*Description*
Upper muck (UM)		
O21	0-2	5YR 2/1, muck, very friable, occasional shells, noncalcareous, clear boundary.
O22	2-10	5YR 2/1, muck, very friable, occasional shells, calcareous.
O1	10-20	5YR 2/1, mucky peat, friable, occasional shells, calcareous, gradual boundary.
Upper silt (US)		
C1	20-28	10YR 3/1, mucky silty clay, friable, occasional shells, calcareous, gradual boundary.
C2	28-36	10YR 3/1, silty clay, friable, occasional shells, calcareous, diffuse boundary.
C3	36-69	10YR 2/1, silty clay loam, sticky, plastic, occasional shells, calcareous, diffuse boundary.
C4	69-111	10YR 2/1, silt loam, sticky, plastic, occasional shells, calcareous, diffuse boundary.
C5	111-138	10YR 2/1, silty clay loam to silty clay, sticky, plastic, occasional shells, calcareous, diffuse boundary.
Lower muck (LM)		
O21b	138-176	2.5Y 4/2, stratified muck and abundant shells, sticky, slightly plastic, calcareous, clear boundary.
O22b	176-194	2.5Y 3/1, muck, sticky, occasional shells, calcareous, diffuse boundary.
O23b	194-231	5Y 2/1, muck, sticky, plastic, no shells, calcareous, gradual boundary.
Lower silt (LS)		
C1b	231-238	5Y 2/1, mucky silty clay, sticky, plastic, no shells, calcareous, blue vivianite flecks on drying, gradual boundary.
C2b	238-251	5Y 5/1, silty clay loam, sticky, plastic, calcareous, clear boundary.
Till		
	251-270	5Y 4/1, loam with gravelly component, calcareous, abundant spruce wood fragments at the upper boundary.

The informal stratigraphic designations used for Colo are also applicable here. Differences between the Colo and Jewell cores lie in the thinner UM zone and thicker US zone at the Jewell bog; a prevalent shell-rich organic horizon also occurs in the upper part of the LM zone at the Jewell site. The LS zone in the Jewell core is thinner than in the Colo

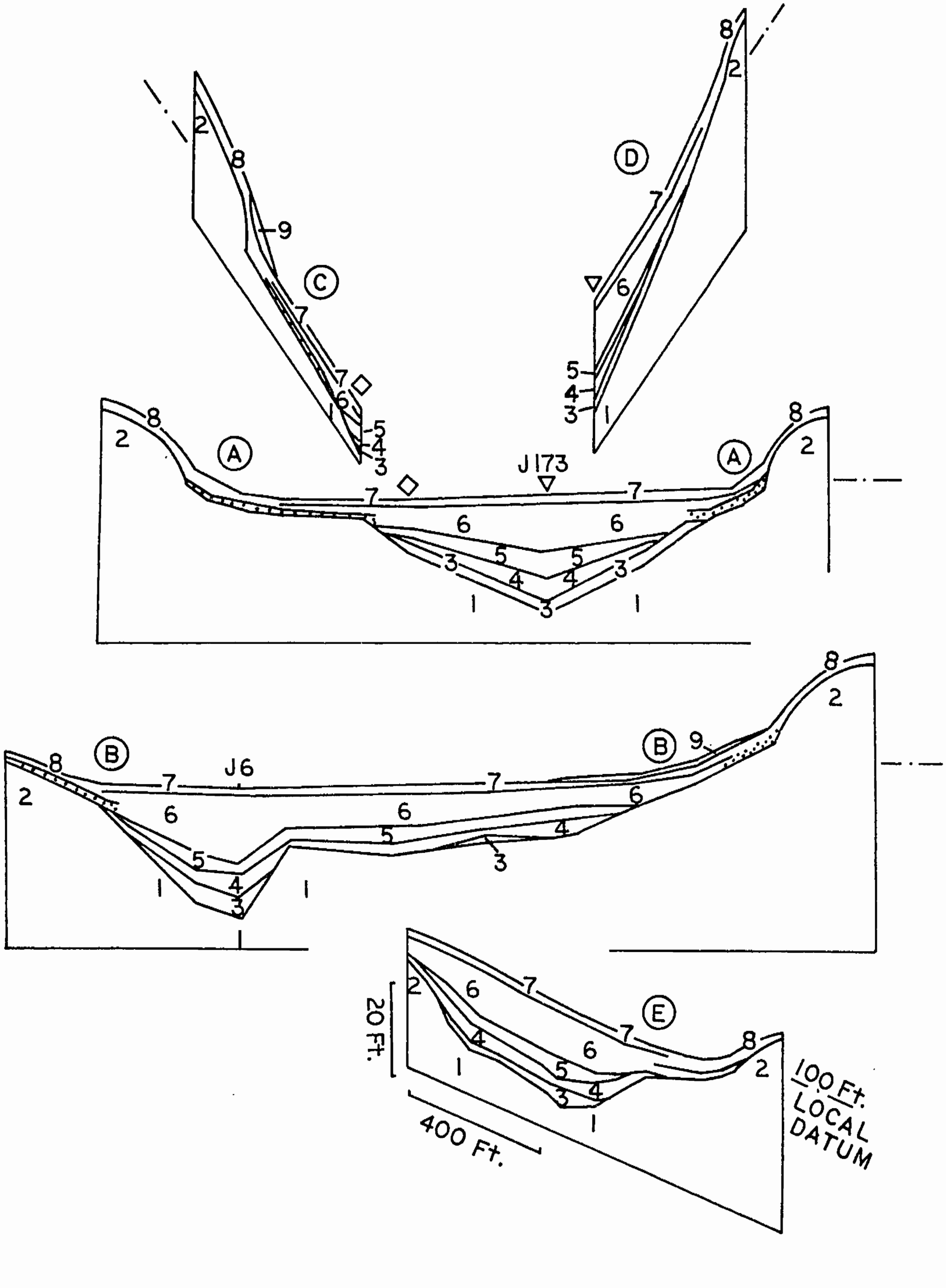


Figure 6. Radial sections showing the stratigraphy of the Jewell bog watershed: unoxidized and unleached Cary drift (1); oxidized and unleached Cary drift (2); lower silt zone (3); lower muck zone (4); shell-rich horizon (5); upper silt zone (6); upper muck zone (7); hillside surficials (8); postsettlement deposits (9). Dotted pattern is toeslope sands (TS).

bog and is characterized by brilliant blue flecks and nodules that develop on aeration from areas of grayish (5B 6/1) mottle. Comparable material has been described in bog environments by Koch (1956, p. 201) and Wright et al. (1963, p. 1377) and in these cases, was identified mineralogically as vivianite, an iron phosphate ($Fe_3P_2O_8 \bullet 8H_2O$).

The cross sections of the Jewell bog shown in (fig. 6) show a general similarity of strata to the Colo bog and the same relationship between bog and hillside sediments. Points of difference are the sporadic LS zone at the Jewell site, the shell-rich horizon in the LM zone and the thicker US zone.

The relationship between bog strata and surficial hillside sediments at the Jewell site can be seen in sections of the detailed study area on the west side of the watershed (fig. 7, see fig. 3). The occurrence of a stone line over the upper slopes indicates an erosional origin of the surficial material. With distance downslope, these surficials gradually change into more organic bog sediment; and the coarse components of the stone line interfinger with the US strata of the bog.

McCulloch, Woden and Hebron Bogs

One profile was sampled in the McCulloch bog for detailed analysis (fig. 8). The sample profile M4 is described.

Profile description of McCulloch bog center profile M4:

Location: 1175 feet N., 220 feet E. of SW cor. SE¼ sec. 32, T. 94 N., R. 24 W., Hancock County, Iowa

Horizon	*Depth (inches)*	*Description*
Upper muck (UM)		
O2	0-10	N 2/0, muck, sticky, slightly plastic, noncalcareous, gradual boundary.
O11	10-22	Mottled 10YR 2/2, N 2/0, mucky peat, nonsticky, nonplastic, noncalcareous, gradual boundary.
O12	22-36	10YR 2/1, mucky peat, slightly sticky, slightly plastic, noncalcareous, gradual boundary.
Upper silt (US)		
C1	36-84	10YR 2/1, mucky silty clay loam, sticky, slightly plastic, occasional shells, calcareous, diffuse boundary.
C2	84-132	5Y 2/1, mucky silty clay loam, sticky, slightly plastic, shells common, calcareous, gradual boundary.

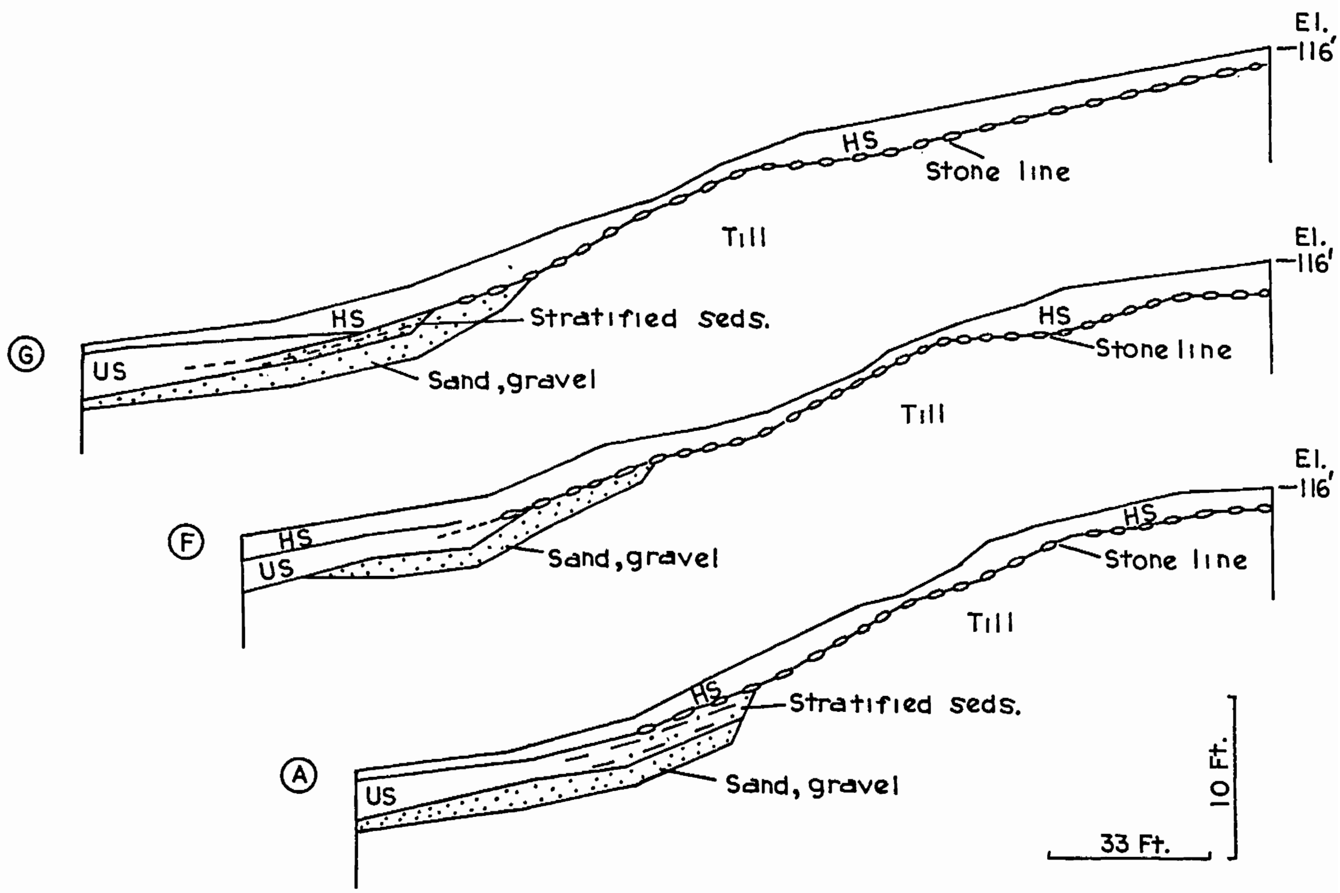


Figure 7. Transects across the east side of the Jewell bog watershed, showing hillside and bog stratigraphy.

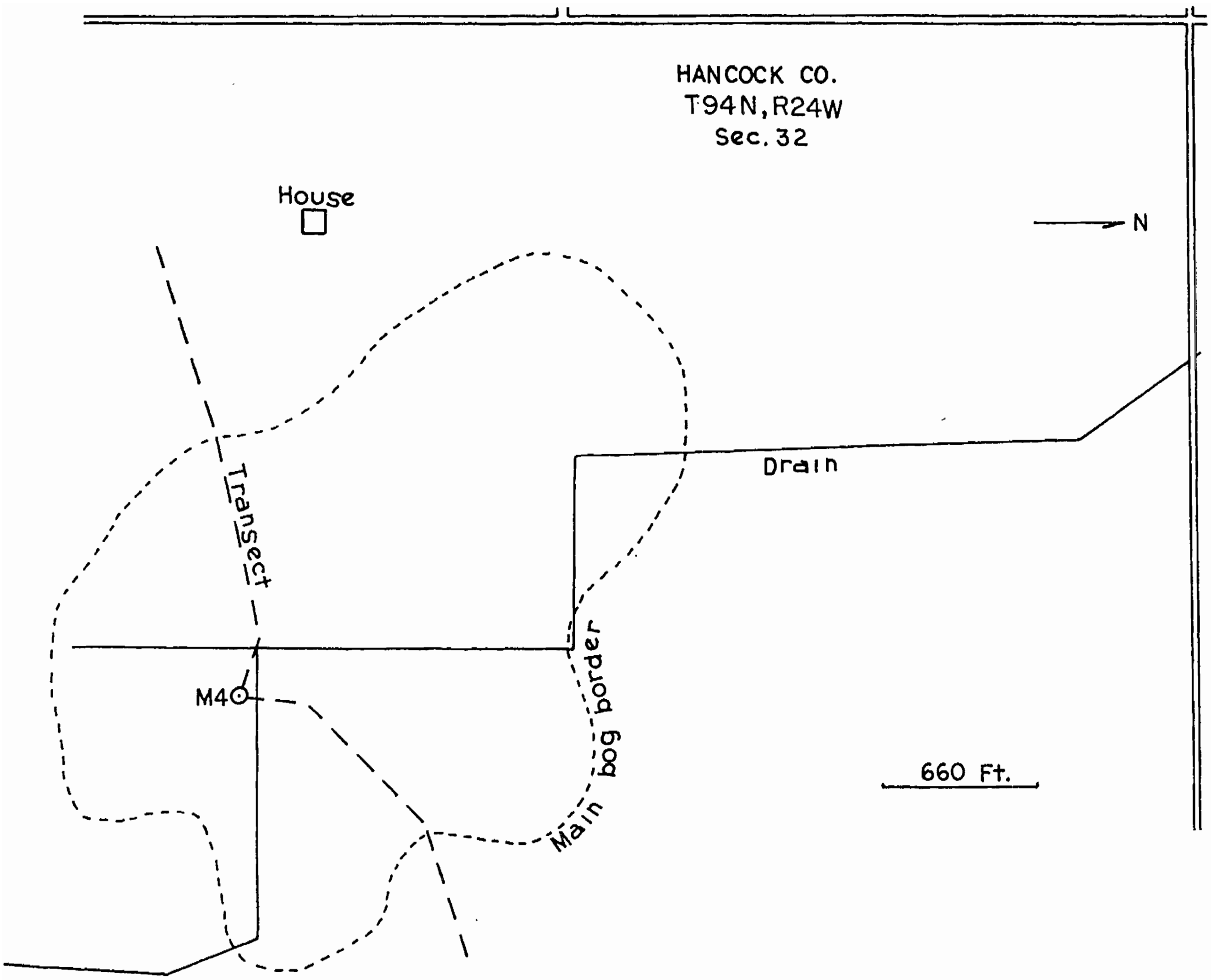


Figure 8. Location of the center profile of the McCulloch bog (M4) and the transect across the bog watershed.

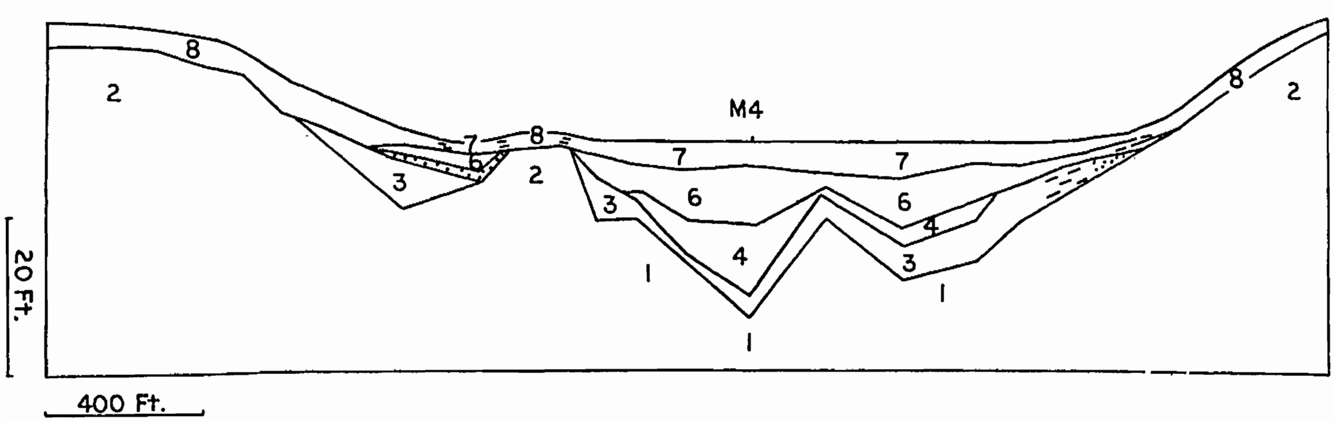


Figure 9. Section across the McCulloch bog watershed, showing bog and hillside stratigraphy: unoxidized and unleached Cary drift (1); oxidized and unleached Cary drift (2); lower silt zone (3); lower muck zone (4); upper silt zone (6); upper muck zone (7); hillside surficials (8). Dotted pattern is toeslope sands (TS).

Lower muck (LM)

O21b	132-150	5Y 2/1, muck, sticky, slightly plastic, no shells, calcareous, gradual boundary.
C1b	150-174	5Y 5/2, mucky silty clay loam, sticky, slightly plastic, abundant shells, clear boundary.
O22b	174-186	10YR 4/2, muck, sticky, slightly plastic, no shells, calcareous, gradual boundary.
O23b	186-234	5Y 3/2, muck, sticky, slightly plastic, calcareous, gradual boundary.

Lower silt (LS)

C2b	234-280	5Y 3/2, silty clay loam, sticky, slightly plastic, noncalcareous, passes abruptly to very coarse material of Cary drift.

McCulloch bog profile M4 has a sequence of mineral and organic zones comparable to the Colo and Jewell bog profiles. The shell-rich stratum within the LM zone in the McCulloch profile is of very limited extent and is not shown as a significant stratigraphic component in the sectional data of fig. 9. A feature of the McCulloch bog is its irregular floor, which results in a complex of depressions. The main depression has an array of strata comparable to both the Colo and the Jewell bogs. On the eastern side, sediments of the LS zone interfinger with the hillside surficials. On the western side of the bog, the stratigraphic sequence is condensed in a small depression in which the LM zone is not represented.

The Woden and Hebron bogs are prepresented here by descriptions of the center cores. Complete sectional data were not obtained; however, a number of exploratory drillings were made in each bog to insure that the profiles chosen for detailed work represented the array of strata near the bog center.

Profile description of the Woden bog center profile W1:

Location: 500 feet S., 1200 feet E. of center of western border of sec. 13, T.97 N., R.26 W., Hancock County, Iowa.

Horizon	*Depth (inches)*	*Description*
O2	0-9	N 2/0, muck, very friable, noncalcareous, gradual boundary.
O1	9-18	2.5Y 2/1, mucky peat, friable, noncalcareous, gradual boundary.
Upper silt (US)		
C1	18-45	10YR 2/1, mucky silty clay loam, friable, weakly calcareous, diffuse boundary.
C2	45-72	N 2/0, mucky silty clay loam, sticky, slightly plastic, weakly calcareous, gradual boundary.
C3	72-84	10YR 2/1, mucky silty clay loam, sticky, slightly plastic, calcareous, gradual boundary.
C4	84-144	10YR 2/1, mucky silty clay loam, sticky, slightly plastic, calcareous, occasional plant fragments, diffuse boundary.
C51	144-192	5Y 2/1, mucky silty clay loam, sticky, slightly plastic, calcareous, plant fragments common.
C52	192-228	Same as C51.
C6	228-252	2.5Y 2/1, mucky silty clay loam, sticky, plastic, calcareous, plant fragments abundant, diffuse boundary.
C7	252-288	10YR 2/1, mucky silty clay loam, sticky, plastic, calcareous, diffuse boundary.
C8	288-312	5Y 3/1, stratified muck and mineral sediment, calcareous, gradual boundary.
Lower muck (LM)		
O2b	312-327	10YR 2/1, muck, sticky, slightly plastic, calcareous, gradual boundary.
Lower silt (LS)		
C1b	327-354	Stratified 5Y 3/1, 5Y 2/1, mucky silty clay loam, sticky, slightly plastic, calcareous, gradual boundary.
C2b	354-372	Stratified 5Y 3/1, mucky silty clay loam, sticky, slightly plastic, calcareous, clear boundary.
C3b	372-378	Stratified 5Y 4/1, mucky silty clay loam, sticky, slightly plastic, calcareous, clear boundary.
C4b	378-390	5Y 4/1, silty clay loam, sticky, slightly plastic, calcareous, clear boundary.
Till		
	390-396	5Y 5/1, loam with gravelly component, calcareous, abundant wood fragments.

Profile description of the Hebron bog center profile H1:

Location: 850 feet S., 675 feet E. of NW cor. SW¼ NW¼ sec. 27, T. 100 N., R. 27 W., Kossuth County, Iowa.

Horizon	*Depth (inches)*	*Description*
Upper muck (UM)		
O21	0-3	10YR 2/1, muck, very friable, noncalcareous, abrupt boundary.
O22	3-12	10YR 3/2, peaty muck, very friable, noncalcareous.
O23	12-19	Same as O22.
Upper Silt (US)		
C1	19-28	10YR 2/2, mucky silty clay loam, friable, noncalcareous, gradual boundary.

C2	28-33	10YR 2/1, mucky silty clay loam, friable, noncalcareous, clear boundary.
C31	33-45	Mottled N 2/0, 1Y 3/3, with fine 2.5YR 3/4, silty clay loam, friable, noncalcareous.
C32	45-56	Same as C31.
C4	56-70	1Y 3/2 with 2.5YR 3/4 along root tracks, silty clay loam, sticky, slightly plastic, calcareous, gradual boundary.
C5	70-78	5Y 6/1 with fine 7.5YR 5/6, mottles, silty clay loam, sticky, slightly plastic, abundant shells, clear boundary.
Lower muck (LM)		
O21b	78-82	10YR 2/1, muck, tough, laminated, weakly calcareous, clear boundary.
O22b	82-90	2.5Y 3/2, muck, slightly sticky, nonplastic, noncalcareous, gradual boundary.
Lower silt (LS)		
C1b	90-100	2.5Y 3/2, mucky silty clay loam, slightly sticky, slightly plastic, calcareous, gradual boundary.
C2b	100-134	5Y 4/1, silty clay loam, sticky, plastic, calcareous, gradual boundary.
C3b	134-146	5Y 4/1, silt loam, slightly sticky, slightly plastic, calcareous, clear boundary.
Till		
	146-152	5Y 4/1, loam with gravelly component, calcareous.

The Woden profile is the thickest of all the center profiles examined. It has the thickest US zone and the thinnest LM zone; the transition between these zones, however, is thick and characterized by stratified muck and silt horizons. The Hebron profile, by contrast, is the thinnest bog center profile examined; but each of the four stratigraphic zones is clearly expressed.

General Stratigraphic Relationships

The strata in each of the profiles described are summarized in fig. 10. It is evident from these data and from the other observations made by Walker and Brush (1963) that a regional bog stratigraphy of alternating organic and mineral sediment zones occurs across the Des Moines lobe.

The general occurrence of such a stratigraphy can best be explained as the result of environmental changes during postglacial time. Bog history on the Des Moines lobe commenced with the retreat of glacial ice and an initial in-filling of the bog depressions with essentially mineral sediments of the LS zone. Subsequently, conditions favored accumulation of organic materials in the bogs, resulting in development of the LM zone. This phase is related to a time of stability on the watershed hillslopes. The gross amount of sediment deposited during the ensuing episode, which formed the US sediments, was sufficient to completely bury the older bog strata. Conditions during this interval favored erosion of the hillslopes and relatively more rapid deposition of mineral sediment in the bog. The final phase, leading to the present, was one of relatively slow mineral sedimentation favoring the development of the organic-rich UM zone of the bogs. This interval represents stabilization of the landscape under prairie conditions comparable to the present. During the investigation of the bog watersheds, observations of postsettlement erosion indicated that the gross amounts are negligible compared with the amounts of geological erosion (see figs. 4, 6).

The hillside surficials at Colo, Jewell and McCulloch bogs are bounded at their base by a more or less continuous stone line. Where the stone line extends to the bog, some of the US zone bog sediments are interfingered with it. The hillside surficials are therefore one facies within the one body of sediment that includes hillside and bog components. Since the LS bog sediments interfinger with the buried coarse deposits in toeslope position of the adjacent hillsides, the two sediments were parts of an earlier sedimentary system with broadly the same sedimentary facies changes as were observed in the US bog zone and associated hillside surficials.

The elements of bog and hillside stratigraphy are summarized in table 2, using the informal designations described earlier and the category terminology of the American Commission on Stratigraphic Nomenclature (1961, p. 649). The stone line is included with the main body of hillside surficial sediment; this follows from the definition of the stone line as a lag gravel (Ruhe 1956) and its position at the base of the pedisediment (Ruhe and Daniels 1958, p. 69).

Table 2. Stratigraphy of the Des Moines lobe of the Cary drift, Iowa.

Substage	Bog member	Bog zone	Hillside zone
Post-Cary	Upper	Muck (UM)	Surficial
		Silt (US)	
	Lower	Muck (LM)	Toeslope sediment
		Silt (LS)	
Cary			Drift

The description of bog materials follows the nomenclature used for soil studies by the U.S. Soil Survey Staff (1960). This is justified insofar as it unifies the terminology for materials in bog and hillside situations. A brief note is made here of the sim-

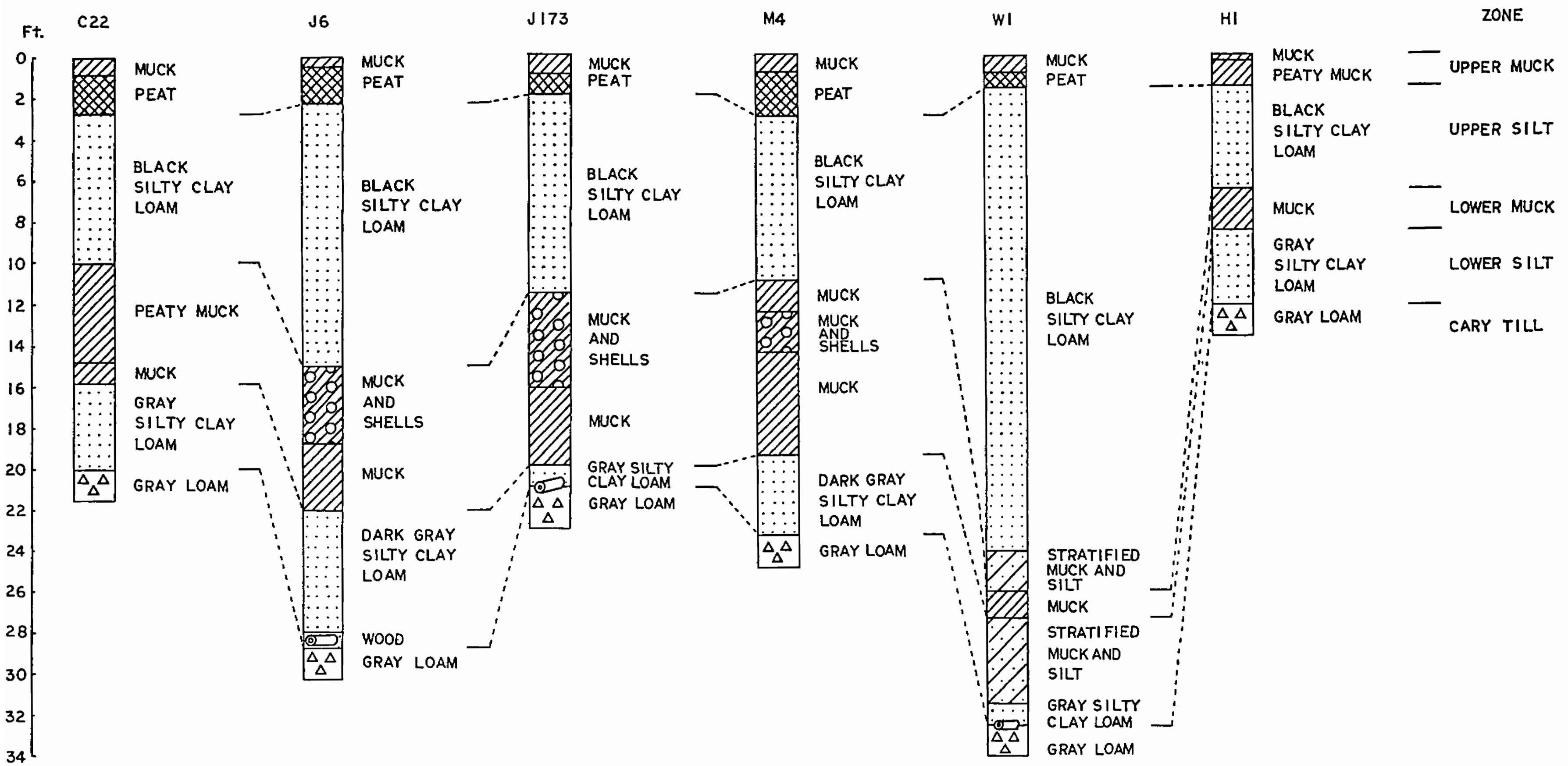


Figure 10. Generalized stratigraphy of the center profiles of Colo (C22), Jewell (J6, J173), McCulloch (M4), Woden (W1) and Hebron (H1) bogs.

ilarities between the bog materials described in this report and materials described elsewhere. The gray silty deposits of the LS may relate to the "blue clays" reported by Rigg (1940) to be washed into depressions during the early stages of glacier retreat. The finely divided olive-colored materials of the LM zone have similarities with some forms of gyttja as described by Dawson (1956, p. 380) and Wright et al. (1963, p. 1377). The black, calcareous, silty strata of the US zone do not seem to have a counterpart in formal bog stratigraphy but may resemble the silty gyttja sediments described for comparable positions in bog profiles of southern Minnesota by Wright et al. (1963, p. 1377). The horizons of the UM zone are comparable to some forms of gyttja but are adequately described by existing soil nomenclature. They are classified as muck (humified), peat (relatively nonhumified), or some intergrade; for example, peaty muck.

Landform and Sediment Relations

In the previous section, evidence was presented to show that Colo, Jewell and McCulloch bog watershed surfaces were adjusted to the latest increments of hillside erosion and bog deposition. The resulting geomorphic surface in each watershed is referred to here as the *late post-Cary surface.* Since the surface age is essentially similar from point to point in these landscapes, the major differences between soils within a watershed relate to sedimentary variations and differences in internal drainage rather than to differences in surface age.

The sediments were identified in the field as either Cary or post-Cary. The criteria for post-Cary were that the sediments in question should show traceable continuity and systematic change across the landscape radially in relation to the bog center and that these sediments, or their counterparts, should be traceable to the LS zone or strata above it. Those sediments that could not be traced laterally or whose counterparts could not be traced laterally to the stratigraphic position of the LS zone or above it, were considered Cary sediments.

Sedimentary units of the post-Cary materials were mapped, and a brief description of each unit is given in table 3. For the purposes of this discussion, the mineral sediment in the upper muck zone is grouped with the upper silt zone strata, and the lower muck zone with the lower silts. The extent of these sedimentary units within each watershed is shown in figs. 11 and 12. In both cases, the units of coarser, hillslope surficial sediment are arranged concentrically about the finer sediments at the bog center. At Jewell bog, however, there is a greater extent of the thicker bog units and a relatively less extensive area of convex hillslopes.

Estimates of quantities of sediment were made from area and thickness data and are presented in tables 4 and 5. The extent of sediment from the bog-hillside transition (sedimentary unit B) to the bog center represents a substantial loss of material from the upper slope areas. In both watersheds, the volume of transported material on lower slopes and in the bog represents more than 75 percent of the total volume of the post-Cary sediment. Estimates of the amounts and rates of hillslope reduction are presented later.

Table 3. Summarized description of Post-Cary sedimentary units mapped in the Colo and Jewell bog watersheds.

Legend	Sedimentary unit	Topography
A	Nonstratified hillside surficials (<3 ft. thick)	Convex and upper concave slopes
B	Stratified hillside surficials and upper (US) bog sediments (2 to 5 ft. thick)	Concave slopes in bog-hillside transition
C	Stratified hillside surficials over LS zone sediments (<5 ft. thick)	Concave slopes in bog-hillside transition
D1	US/LS (5 to 10 ft. thick)	Bog or minor depression
D2	US/LS (10 to 20 ft. thick)	Bog
D3	US/LS (20 to 30 ft. thick)	Bog

Table 4. Area and thickness data for sedimentary units mapped in the Colo bog watershed.

Sedimentary unit	Percent of total area	Acres	Av. thickness of sediment (ft.)	Quantity of sediment (acre-ft.)
A	56.1	51	1.5	76.5
B	21.3	19	3.5	66.5
D1	19.9	18	7.5	135.0
D2	2.2	2	15.0	30.0
D3	0.5	0.5	25.0	12.5
Total area	100	90.5		

Table 5. Area and thickness data for sedimentary units mapped in the Jewell bog watershed.

Sedimentary unit	Percent of total area	Acres	Av. thickness of sediment (ft.)	Quantity of sediment (acre-ft.)
A	43.1	96	1.5	144
B	27.4	61	3.5	214
C	1.8	4	2.5	10
D1	8.0	18	7.5	135
D2	11.7	26	15.0	390
D3	7.4	17	25.0	425
Overburden (O.B.)	0.6	1		
Total area	100	223		

Properties of Cary Sediments

Part of this discussion relates to the weathering profile of the Cary drift. The terminology used for the drift weathering zones follows Kay and Graham (1943, p. 203) and was related to the pedological profile by Scholtes et al. (1951, p. 296). The essential horizons, commencing with the deepest, are: the unoxidized and unleached zone (U), unmodified geo-

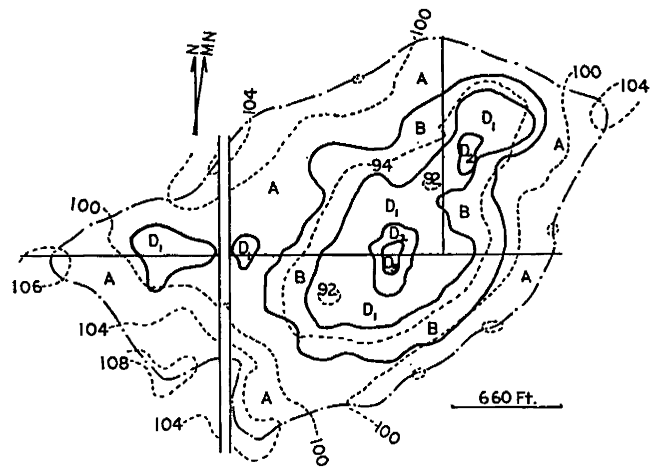
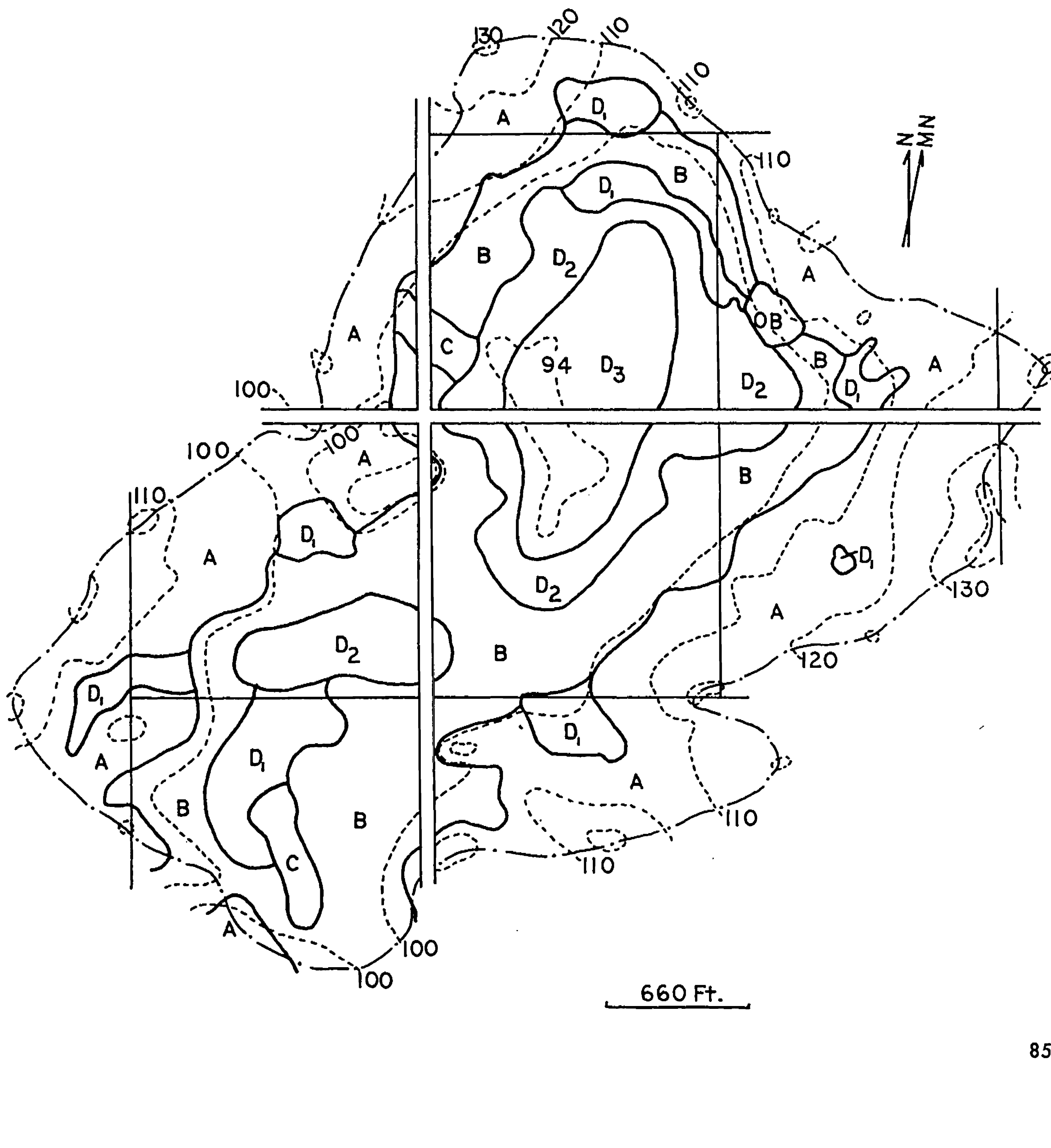


Figure 11. (left) Map of post-Cary sediments in the Colo bog watershed. The map legend is defined in table 3.

Figure 12. (below) Map of post-Cary sediments in the Jewell bog watershed. The map legend is defined in table 3.



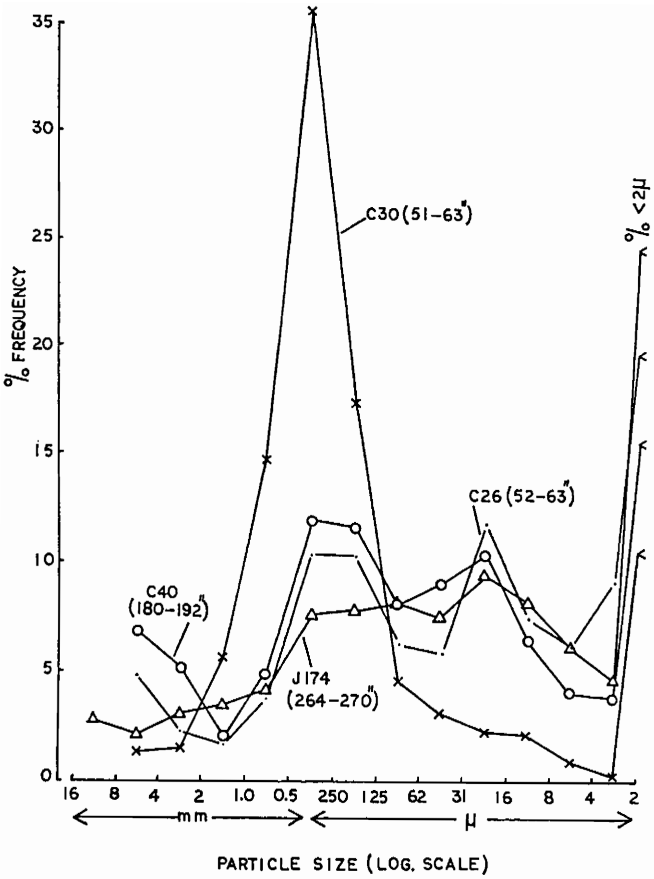


Figure 13. Particle-size distribution diagrams for selected samples of Cary sediment.

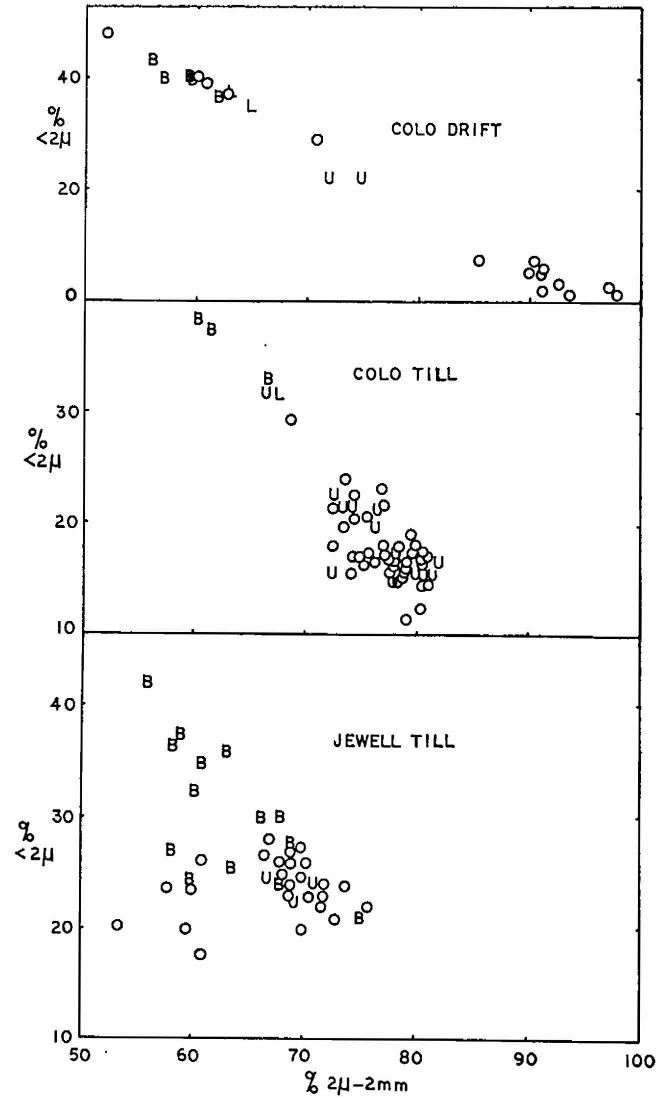


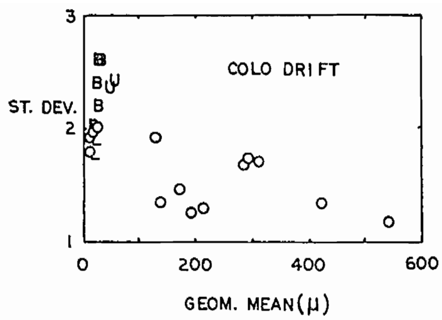
Figure 14. Plot of particle-size data for drift and till in the Colo bog watershed and till in the Jewell bog watershed.

logical material; the oxidized and unleached zone (O); the unoxidized and leached zone (L), also the C horizon of the pedological profile; the zone of chemical decomposition, equivalent to the pedological B horizon; and the organic zone or soil A horizon at the surface. Soil A horizons and all demonstrably post-Cary sediments are excluded from this discussion.

Throughout this and later sections, the particle size mean (microns) and standard deviation (phi units; see Krumbein and Pettijohn 1938, p. 245) data are for the range 2 microns to 2 mm. One justification for this procedure is that the coarse material found in the drift ranges from sand-size to boulders many feet in diameter. The boulders cannot be handled satisfactorily in a particle-size analysis, and even the smaller pebble-size material creates problems in subsampling. Consequently, the fractions greater than 2 mm are omitted from calculations. A second justification lies in the nature of the drift sediments. The size distribution curves usually reach a maximum within the 2 micron to 2 mm range, with minima in the vicinity of 2-micron and 2-mm diameters. Examples of these properties are shown for a range of samples in fig. 13.

Particle-size data for stratified drift[4] in the Colo watershed and till in the Colo and Jewell watersheds are given in figs. 14 and 15. The stratified sediments of the drift cover the range of properties of the till, and the highly significant relationship between geometric mean and standard deviation for the drift indicates a degree of transportation and sorting consistent with the definition of drift. By contrast, the tills have a relatively narrow range of standard deviation and a nonsignificant (5-percent level) relationship between geometric mean and standard deviation. These data suggest that the till samples have not been reworked by water. There is a considerable degree of overlap of particle-size prop-

[4]Terminology used in relation to glacial deposits follows the definitions of the American Geological Institute (1957). *Drift* refers to the whole range of materials transported and deposited by glacial action, including water-deposited sediments. *Till* refers to that part of the drift that is stiff and unstratified.



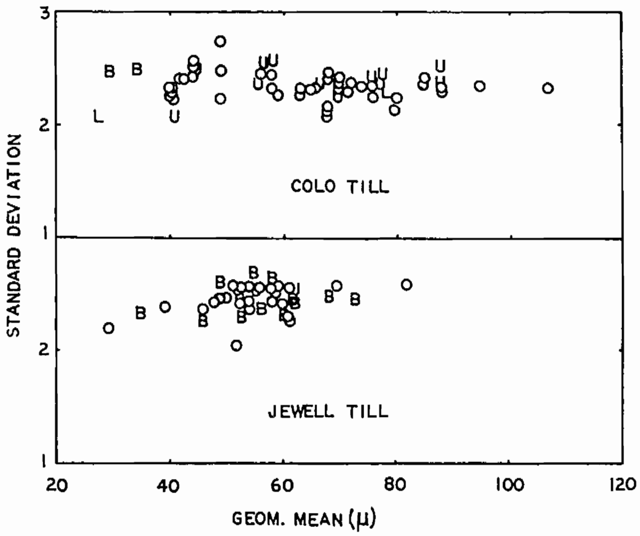


Figure 15. Plot of the standard deviation and geometric mean for the particle-size range 2 microns to 2 mm for drift and till in the Colo bog watershed and till in the Jewell bog watershed.

erties in the weathering zones of the till profiles. The unoxidized and unleached zone and the oxidized and unleached zone have the same range of sedimentary properties, but a greater proportion of B horizon samples occurs in the higher range of percentage less than 2 microns. No systematic trends were observed within single profiles, such as increase in geometric mean with increase in percentage less than 2 microns clay, which would suggest that the increased clay was caused by pedological weathering. Rather, the particle-size properties of the B horizons fit into the general pattern of particle-size properties of the other weathering zones; namely, as the percentage less than 2 microns increases, so the geometric mean decreases (fig. 16). A simple interpretation of the B horizon particle-size properties as being entirely of geological origin is not valid, however, since large losses have occurred from the coarse end of the particle-size distribution because of leaching of carbonate fragments (Kay and Graham 1943, p. 222).

The data in figs. 14 and 15 can be used to define practical limits for the sedimentary properties of the till. A range of percentage less than 2 microns clay from 15 to 25 and a standard deviation range of 2.0 to 2.6 would exclude more than 80 percent of samples classified as drift in the Colo watershed and would include more than 80 percent of samples classified as till. The till in the Jewell watershed is more clayey than that at the Colo site; limits of 20 to 30 percent less than 2 microns clay and a standard deviation range of 2.0 to 2.6 would include most samples classified as till in this watershed.

Other miscellaneous properties of the Cary sediments are listed in table 6.

Table 6. Gravel, carbonate and bulk density data for Cary sediments.

Property	Weathering Zone	Avr.	Range	Number of observations
% gravel (>2 mm)	Till (Colo) B hor. (B)	1.0	0.3-1.7	3
	ox. unl. (O)	4.8	1.1-10.4	37
	unox. unl. (U)	5.8	1.4-11.9	14
	Drift (Colo) B hor. (B)	2.0	0.2-5.1	5
	ox. unl. (O)	3.5	0.2-7.8	12
	unox. unl. (U)	4.5	3.3-5.6	2
	Till (Jewell) B hor. (B)	5.9	0.7-15.9	14
	ox. unl. (O)	8.9	2.0-26.4	25
	unox. unl. (U)	7.2	5.5-8.2	3
% calcium carbonate equivalent	Till (Colo) ox. unl. (O)	15.0	8.7-22.5	36
	unox. unl. (U)	20.0	14.9-39.2	10
	Drift (Colo) ox. unl. (O)	9.9	1.2-16.7	15
	unox. unl. (U)	15.4	15.0-15.8	2
	Till(Jewell) ox. unl. (O)	18.9	11.0-24.6	26
	unox. unl. (U)	18.3	17.5-19.8	3
Bulk density (gm/cc)	Drift and till (Colo)	1.63	1.34-1.80	10
	Till (Jewell)	1.62	1.52-1.71	10

Properties of Post-Cary Sediments

The particle-size properties of post-Cary sediments in the Colo and Jewell watersheds can be readily interpreted in terms of the stratigraphy outlined in a preceding section and the lateral changes that take place within the strata. The gross particle-size changes within upper and lower sedimentary members are represented in figs. 17 and 18. These indicate that surficial sediments become progressively finer and better sorted with distance from the watershed perimeter towards the bog center. At both the Colo and Jewell sites, however, these sediments are stratified into coarse and fine in a narrow zone of surficial differentiation at the edge of the bog. Evidently, sedimentary conditions for both upper and lower members were such that coarser materials were preferentially deposited in this zone, and only the finer

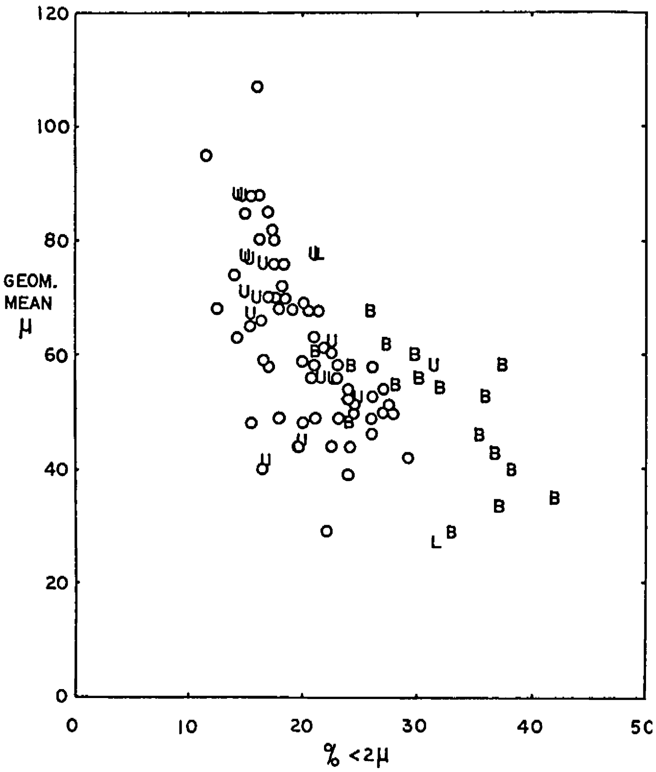


Figure 16. Plot of geometric mean and percent clay (<2 microns) for Cary till samples in the Colo and Jewell bog watersheds.

fractions moved within the bog environment. The geometric mean data, in particular, show a characteristic spread within the zone of differentiation at the edge of the bog.

A closer study of these changes was made in a small enclosed depression on the east side of the Jewell watershed, commencing at site J80 shown in fig. 3. The stratigraphy of a section (JSS) across half of this depression is shown in fig. 19. The hillside surficial layer overlies a distinct stone line above the till in the upper slope positions; below the mid-slope position, surficial sediments overlie the LM zone of the lower bog member, which is up to 8 feet thick at the center of the depression. Figure 20 shows the progressive particle-size changes within the surficial layer from the perimeter of the depression watershed to its center. The same kind of changes occur here as in the Colo and Jewell watersheds, except that the stratified material in the zone of differentiation is somewhat closer to the center of the depression, because of the proportionately greater encroachment of the hillside sediment. In fig. 21, empirical curves have been fitted to selected data of the surficial sediment. These curves further substantiate that systematic changes occur within the surficial materials across the watershed hillslopes. The presence of systematic changes with distance across the watershed slopes, of sedimentary differentiation at the edge of the bog and the preferential movement of fine sediments into the bog center, all indicate that alluvial transport is the dominant process moving the surficial sediments.

The occurrence of a till-derived surficial sediment above the stone line at the hillcrest, as shown in fig. 19, is anomalous as a feature related to postglacial erosion. It seems likely that the occurrence relates to an earlier erosion and deposition phase, possibly late glacial in age. Subsequent surficial processes have made this older feature indistinguishable from the later erosional and depositional features that characterize sideslopes and toeslopes. The depositional nature of the surficial sediments on the Cary drift

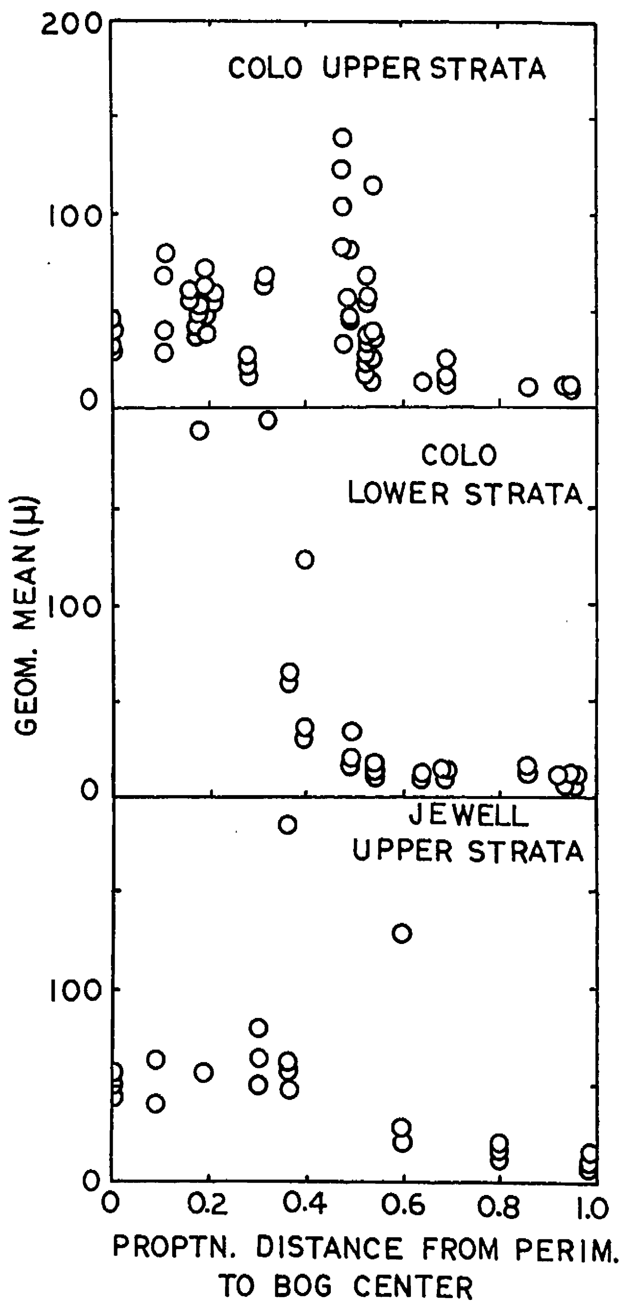


Figure 17. Plot showing the progressive change in geometric mean of surficial sediments from the bog watershed perimeter to the bog center.

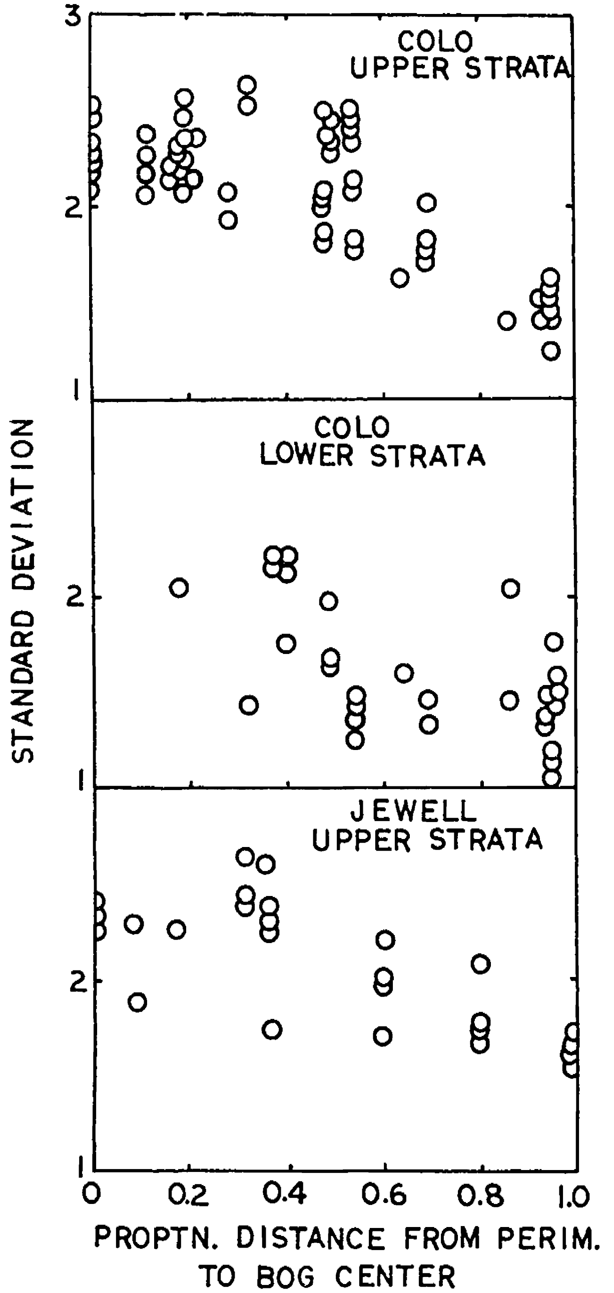


Figure 18. Plot showing the progressive change in sorting, as indicated by particle-size standard deviation, for surficial sediments from the bog watershed perimeter to the bog center.

have been reported previously by White (1953) and Wallace and Handy (1961). The sedimentary characteristics of these deposits have been inherited by the soils that formed on them and thus, became an important factor in soil profile development.

The Soils

Soil Maps[5]

The soils were mapped in the Colo and Jewell watersheds by using a comprehensive legend designed to reflect differences in landscape position and parent materials. Apart from the differences in topography that exist between Colo and Jewell areas, the Cary sediments at Jewell are finer tex-

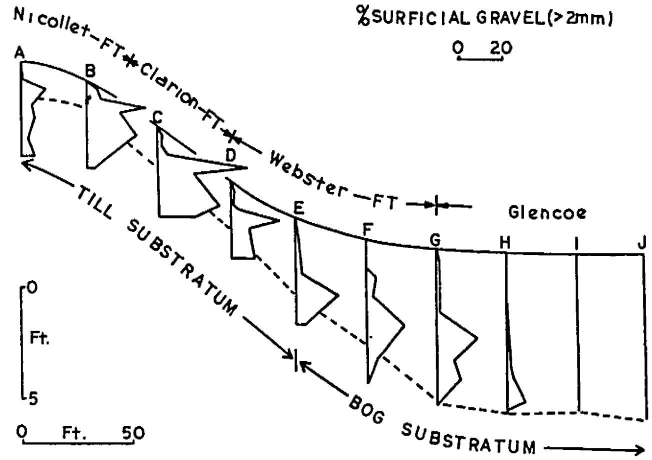


Figure 19. Plot of percentage gravel (> 2 mm) in the surficial sediment and soil on the side of a small enclosed depression along the eastern perimeter of the Jewell bog watershed. Site A of this JSS traverse is at the location of J80 in fig. 3.

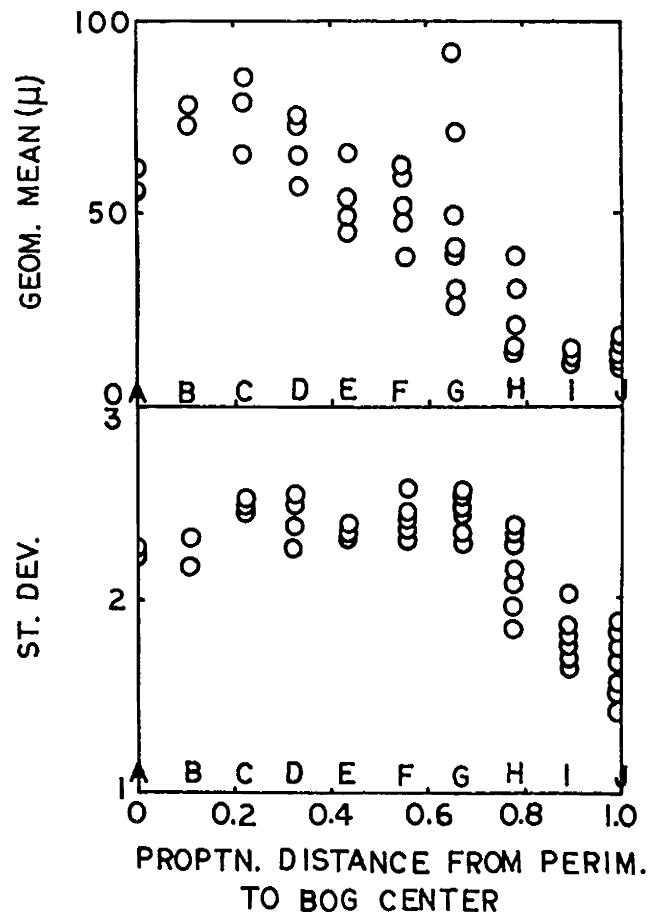


Figure 20. Changes in particle-size geometric mean and standard deviation in surficial sediments on the side of a small enclosed depression along the Jewell bog watershed perimeter.

[5]The author is indebted to J. D. Highland and C. S. Fisher of the U.S. Department of Agriculture, Soil Conservation Service, for establishing the mapping legend and carrying out a large share of the mapping program.

tured than those at the Colo site. The fine-textured parent material forms a soil sequence homologous to the Clarion, Nicollet and Webster series. The Cary sediments are similar to those studied by Hidlebaugh (1959) and are given the same series designations; for example, Clarion-FT, Nicollet-FT.

The mapping units are listed in table 7, with notes on their relationship to established or proposed series. The bog legend is designated by the letter P rather than by numbers. Each numbered legend has three parts; for example, 1-6-2. The first number refers to the series or series variant; in this case, the number, 1, refers to the Clarion series. The second number, 6, refers to the slope phase; in this case, the 5 to 9 percent slope class. The third number is an erosion class designation based on A horizon thickness. Thus, mapping unit 1-6-2 represents the Clarion series on 5 to 9 percent slopes, with 3 to 7 inches of A horizon. The slope classes in table 7 are as follows: depressions (0); 0-1 percent (1); 1-2 percent (2); 2-5 percent (3); 5-9 percent (6); 9-14 percent (11); 14-18 percent (17). The erosion classes in table 7 are: greater than 12 inches of A horizon (0); 7-12 inches (1); 3-7 inches (2); less than 3 inches (3). Soils fitting the central range of a series are listed without special notation; soils within the series range, but with a property at one end of the range, are qualified accordingly under the tabular comment heading. Other soils are closely related to established series

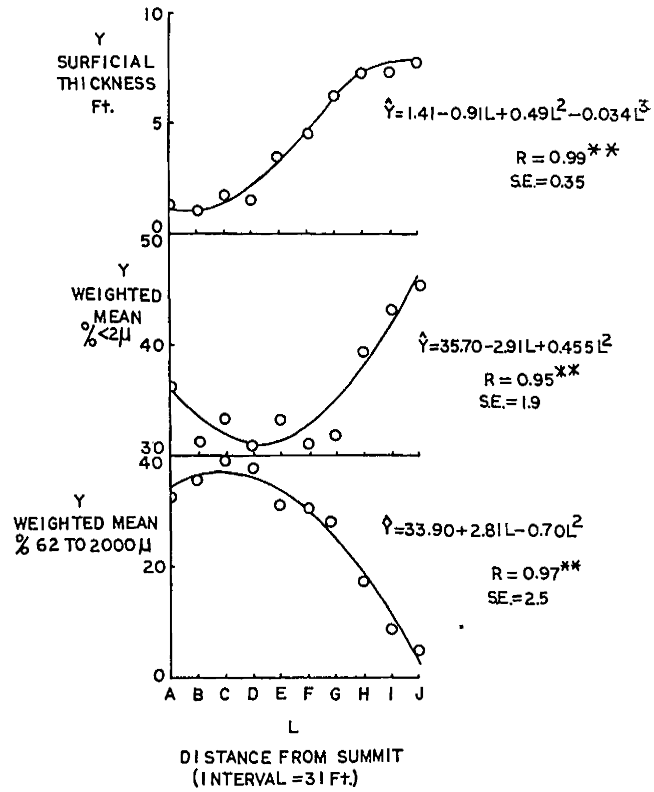


Figure 21. Plot of changes in thickness and particle-size parameters for the surficial sediments on the side of a small enclosed depression along the Jewell bog watershed perimeter. Statistical significance at the 0.01 level is indicated by **.

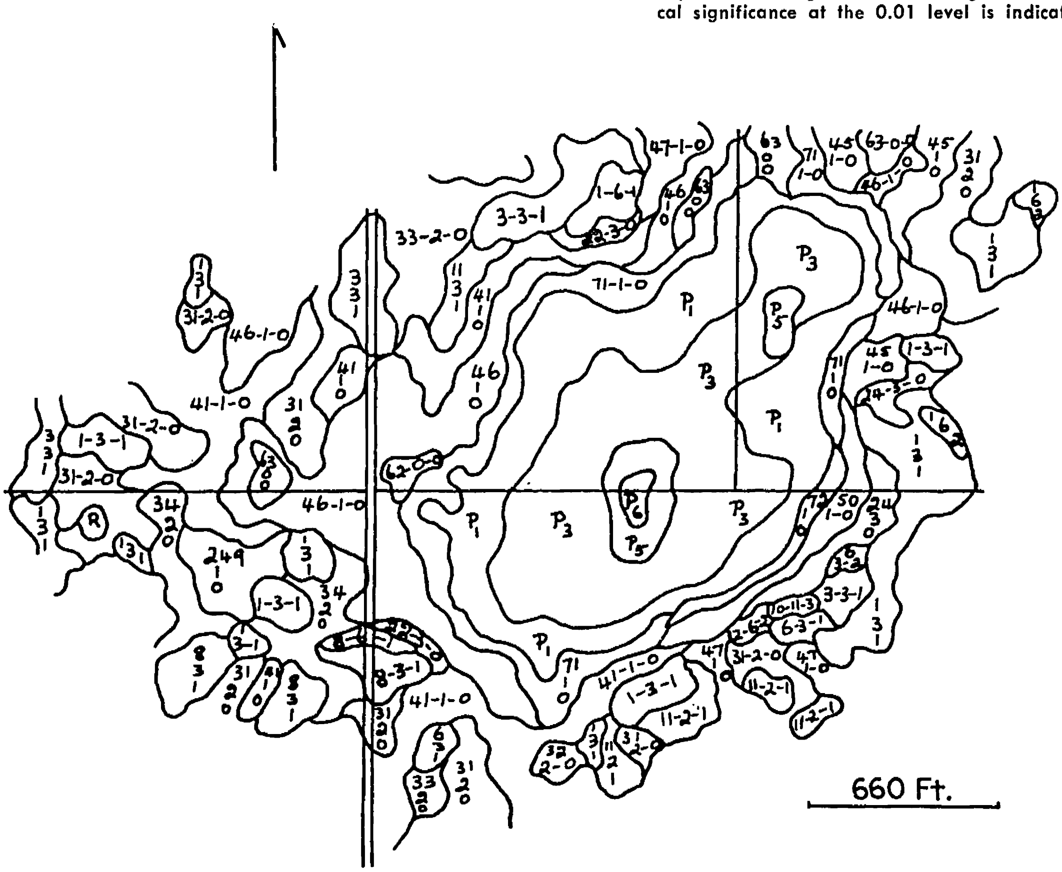


Figure 22. Soil map of the Colo bog watershed. The map legend is defined in table 7.

but fall outside the specified range; such soils are designated as variants. Other variations occur in soils where there is a range of properties comparable to an established series but also a consistent difference with respect to one important property; for example, stratification of the Cary sediment in Webster soils. This is accommodated by placing (2) after the series name. Thus unit 45-1-0 becomes Webster (2).

Table 7. Summarized notes for soil mapping units in the Colo and Jewell watersheds.

Unit	Slope and erosion phases	Drainage	Series relation	Comments
1	1-3-1 1-6-1 1-6-2	Well	Clarion	
2	2-3-1 2-6-1 2-6-2	Well	Clarion	Shallow carbonates
3	3-3-1	Well	Clarion	Deep carbonates
6	6-3-1 6-3-2	Well	Clarion (var.)	Stratified drift at 24-36 in.
8	8-3-1	Well	Clarion (var.)	Stratified drift at 36-48 in.
9	9-11-2 9-17-3	Well	Storden	
10	10-11-3	Excessive	Storden (var.)	Stratified drift
11	11-2-1 11-3-1	Mod. well	Clarion	
22	22-3-0	Mod. well	Terril	
23	23-3-0	Imperfect	Terril	
24	24-3-0	Imperfect	Nicollet (var.)	Cumulic
26	26-1-0 26-3-0	Poor	—	Local alluvium
31	31-2-0 31-2-1	Imperfect	Nicollet	
32	32-2-0	Imperfect	Nicollet	Shallow carbonates
33	33-2-0	Imperfect	Nicollet	Deep carbonates
34	34-2-0	Imperfect	Nicollet	Stratified drift
35	35-3-1	Imperfect	Nicollet (var.)	Calcareous surface
41	41-1-0	Poor	Webster	
42	42-1-0	Poor	Webster (var.)	Calcareous surface
45	45-1-0	Poor	Webster (2)	Stratified drift
46	46-1-0	Poor	Webster (2) (var.)	Stratified drift, calcareous surface
47	47-1-0	Poor	Webster (2)	Stratified drift, deep carbonates
49	49-1-0	Poor	Webster	Cumulic, deep carbonates
50	50-1-0	Poor	Calco (loamy var.)	Local alluvium
61	61-1-0	Poor	Glencoe	
62	62-0-0	Poor	Glencoe (var.)	Calcareous surface
63	63-0-0 63-1-0	Poor	Glencoe (2)	Cumulic, non-calcareous surface
64	64-0-0	Poor	Glencoe (2) (var.)	Cumulic, calcareous surface
71	71-1-0	Poor	Harpster	
72	72-1-0	Poor	Harpster (var.)	Cumulic
73	73-1-0	Poor	Harpster (2)	Stratified drift
101	101-3-1 101-6-1 101-6-2 101-11-2	Mod. well	Clarion-FT	Fine textured till
102	102-3-1 102-6-2 102-11-2	Mod. well	Clarion-FT	Shallow carbonates
103	103-3-1	Mod. well	Clarion-FT	Deep carbonates
109	109-6-2 109-6-3 109-11-3 109-17-2	Mod. well	Storden	Fine textured till
131	131-1-0 131-2-0 131-3-0 131-6-1	Imperfect	Nicollet-FT	Fine textured till
133	133-1-0 133-2-0 133-3-0	Imperfect	Nicollet-FT	Deep carbonates
141	141-1-0 141-2-0 141-3-0	Poor	Webster-FT	Fine textured till
142	142-1-0	Poor	Webster-FT (var.)	Calcareous surface
148	148-1-0 148-2-0 148-3-0	Poor	Webster-FT (var.)	Deep carbonates
149	149-1-0 149-2-0	Poor	Webster-FT	Cumulic, deep carbonates
201	201-6-1	Imperfect	Nicollet-FT (2)	Fine textured till, silty clay B hor.
249	249-1-0 249-2-0	Poor	Webster-FT (2)	Fine textured till, silty clay B hor.
P1	<2% slope	Very poor	—	Mucky, calcareous surface over stratified surficials and upper bog sediment
P2	<1% slope	Very poor	—	As in P1 but with lower bog sediment substratum
P3	<1% slope	Very poor	—	UM/US/LS/drift
P4	<1% slope	Very poor	—	US/LM/LS/drift (10-20 ft.)
P5	<1% slope	Very poor	—	UM/US/LM/LS/drift (10-20 ft.)
P6	<1% slope	Very poor	—	UM/US/LM/LS/drift (20-30 ft.)

The soil maps at Colo and Jewell are shown in figs. 22 and 23. The map of the Colo watershed shows the characteristic Clarion soil toposequence of the Clarion-Webster association (Oschwald et al., 1965). Clarion and Nicollet soils occur on upper slopes, and Webster soils generally occur on lower slopes or upper slopes of very gentle gradient. Harpster and related soils form a rim of calcareous surface soil around the bog edge, and these soils merge into the highly organic bog soils of the main depression. With distance toward the bog center, the soils become more organic and the sediments thicker. This trend is represented in the bog units P1, P2 and P3. In the central bog area, the characteristic double-bog sequence UM/US/LM/LS is represented by mapping units P5 and P6.

Most of the Jewell watershed soils are developed on heavier textured material than occurs at the Colo site. The mapping units 101, 131 and 141 (Clarion-FT, Nicollet-FT and Webster-FT) on the finer-textured till parallels the 1, 31, 41 (Clarion, Nicollet and Webster) sequence on the loam till in the Colo watershed, except that the soils of unit 101 are moderately well-drained. The more frequent stratification of drift materials at the Colo site is reflected in a larger area of stratified units. At the Jewell site, however, a greater soil area is developed in stratified post-Cary sediment (units 49, 73) on lower hillslopes. This is consistent with the greater area of stratified surficial material recorded for the Jewell watershed in table 5.

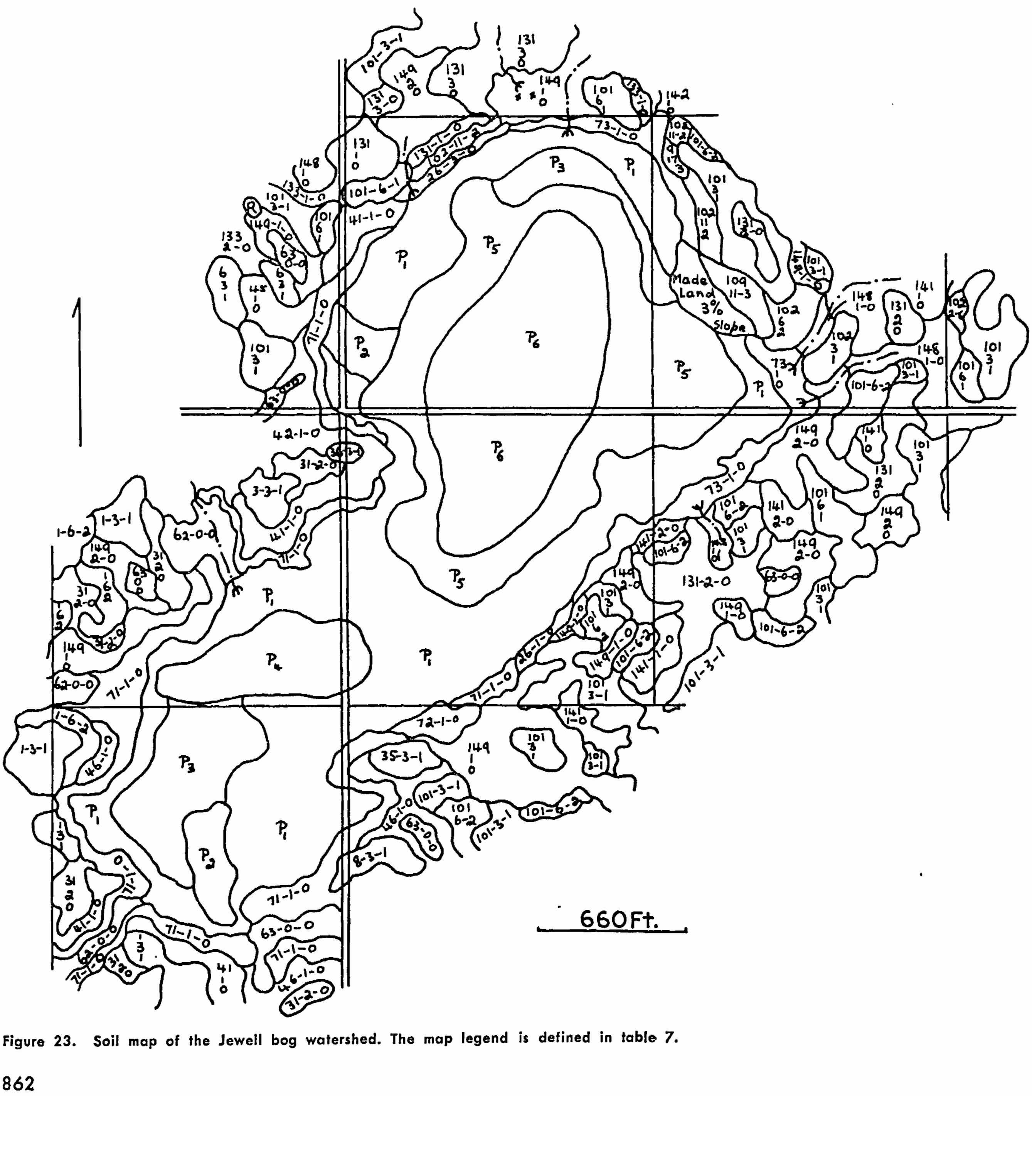


Figure 23. Soil map of the Jewell bog watershed. The map legend is defined in table 7.

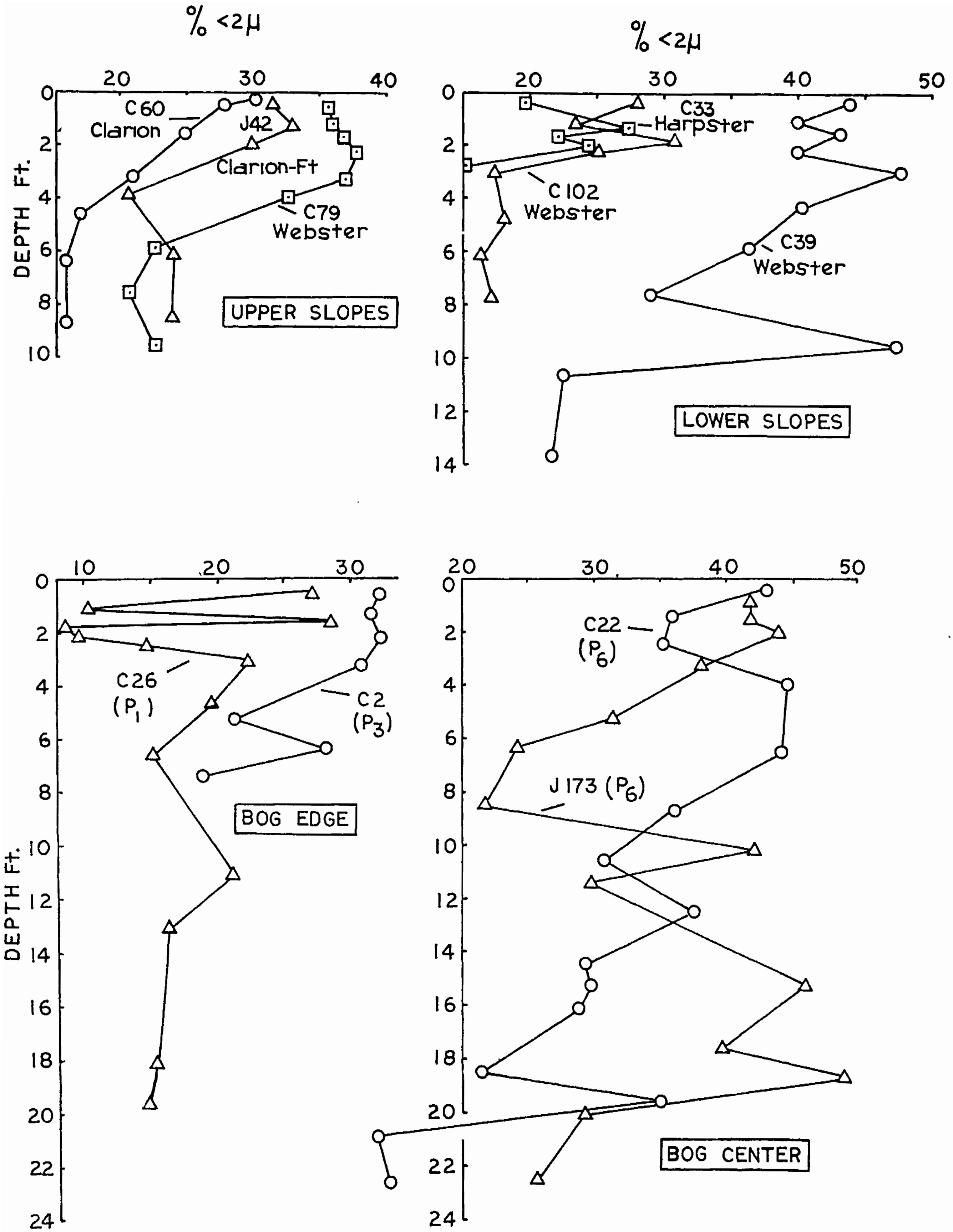


Figure 24. Plot of percentage clay (< 2 microns) profiles for selected sites in the Colo and Jewell bog watersheds.

The location of each soil profile discussed in this section is shown in figs. 2 and 3. Soil profile data are grouped together on the basis of topographic setting for this discussion. The first group comprises soils of upper slopes, including gently sloping hillcrests. A second group includes soils on lower slopes, and the third group includes soils in small depressions or at the edge of major bog areas. The fourth group comprises deep, bog-center profiles.

Profiles of percentage <2 microns clay of selected soils of each topographic grouping are shown in fig. 24. The Clarion soil (C60) at Colo had less clay throughout than the Clarion-FT soil (J42) on the finer-textured till at Jewell. The Webster soil (C79), a poorly drained profile on a very gently sloping surface near the Colo watershed perimeter, has somewhat more clay than either of the other soils and has a distinct clay maximum in the profile. The effect of stratification of the parent material is evident in the lower slope and bog-edge soil groups. Webster profiles C102 and C39 at the Colo site show an interesting contrast; the former is developed in stratified post-Cary sediment over till, whereas the latter is developed in stratified drift. The Harpster soil (C33) at Colo is also developed in stratified surficial sediment over till. The bog center profiles, C22 and J173, show some variability with depth in percentage <2 microns clay. In both cases, there is evidence of two clay maxima which seem associated with the organic-rich profile zones.

Organic carbon profiles for three of the topographic groups are plotted in fig. 25. These show greater organic carbon in profiles with the greater amount of <2 microns clay and a general trend toward increased organic carbon with closer proximity to the bog center. The organic carbon profiles of bog center situations are shown in fig. 26. These include the center profiles from all bogs sampled. All profiles show the distinct double organic carbon maximum, although the lower maximum is less distinct in the McCulloch and Woden bog profiles than in other bogs. These data support the field observations recorded earlier in this report and confirm the occurrence of a general bog stratigraphy on the Cary drift in Iowa.

Calcium carbonate equivalent profiles of fig. 27 show the general tendency for a greater depth of leaching in upper slope situations and a progressively closer approach of the carbonate horizon to the surface with distance downslope. This trend culminates in the carbonate-rich surface horizons of the Harpster soil (C33) at the edge of the bog. Usually the surface horizons of bog profiles are noncalcareous to weakly calcareous. In these profiles only the Harpster soil shows a zone of secondary carbonate accumulation; the maxima in the lower horizons of the bog profiles are related to heavy shell accumulations. An exception to this generalization about hillslope

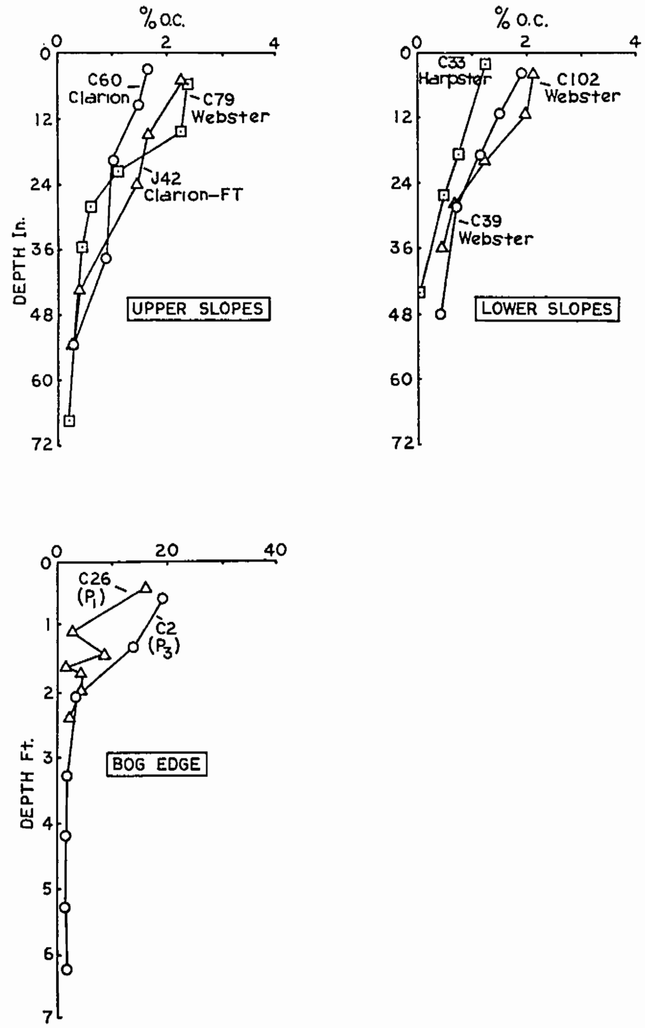


Figure 25. Plot of percentage organic carbon (O.C.) for selected profiles in the Colo and Jewell bog watersheds.

soils is the Storden series, which is calcareous at the surface and occurs in steep, upper slope situations. Data for the Storden soils are not discussed here, although the series was mapped in both watersheds.

Bulk-density data are plotted in fig. 28 for profiles along a section (JSS) across a small depression on the eastern side of the Jewell watershed (fig. 3). These data show the progressive decrease in density from the hillcrest to the depression, which is associated with an increase in <2 microns clay and organic matter. Bulk densities for the Colo, Jewell and McCulloch bog center profiles, 0.13 to 0.95 gm/cc, show a reverse trend to the organic carbon profiles of fig. 27, further indicating the close relationship between bulk density and organic carbon content (fig. 29). These data can be fitted by an empirical equation of the form $Y = 1/(a + bX)$, where Y is the bulk density and X is the organic carbon content. The bulk density values are comparable to other values obtained for peat in Iowa by Richlen (1957) and to values of 0.10 to 0.82 gm/cc obtained for a raised bog reported by Mattson and Koutler-Andersson (1954).

Some of the trends in soil properties across the landscape are shown by data in the JSS transect on the east side of the Jewell watershed. In surficial sediment above the stone line <2 microns, clay increases and geometric-mean size decreases downslope (fig. 30). Both sets of data suggest that the soil on the hillcrest position has distinctive properties and probably represents a fine-textured capping of glacial origin, comparable to that described in an adjacent area by Hidlebaugh (1959). Fine-textured cappings over Cary till have also been described in South Dakota by Wilding and Westin (1961). On the sideslopes of the JSS traverse, however, stratigraphic relationships clearly establish the postglacial age of the surficial sediment above the stone line. The nature of the stone line in fig. 30 as a lag gravel, as defined by Ruhe (1956), is also established by the coarse material deposited preferentially at the side of the depression; only fine materials have moved to the center.

The organic carbon and calcium carbonate equivalent data of fig. 31 show the manner in which processes subsequent to deposition have modified the surficial sediments to give characteristic soil properties. There is a greater enrichment with organic matter of the soils on the floor of the depression, although they are not technically mucks or peats. The occurrence of a calcareous surface soil at the edge of the depression is consistent with the soil pattern just described, except that in this case, the soil is a Webster-FT (calcareous surface) rather than a Harpster profile.

Vegetational Data

Pollen Analyses

The pollen data discussed here are for the center profile of the Colo bog, C22. These data were presented in an earlier publication by Walker and Brush (1963) and are shown in revised form in fig. 32 with the broad stratigraphic divisions of the profile. The basal-fine sediments of the LS zone contain negligible amounts of pollen, but the upper part of the LS sediments contain numerous conifer (*Pinaceae*) pollen. Through the LM zone, conifers diminish; but other tree pollens, including alder (*Alnus*), increase together with hardwoods, such as birch (*Betula*). The transition from LM zone to US zone is characterized by a decrease in tree pollens and an increase in herbaceous pollens. Other herbs, such as the goosefoot family (*Chenopodiineae*), reach a maximum in the upper part of the US zone, and grass pollen (*Gramineae*) becomes dominant at the transition from US

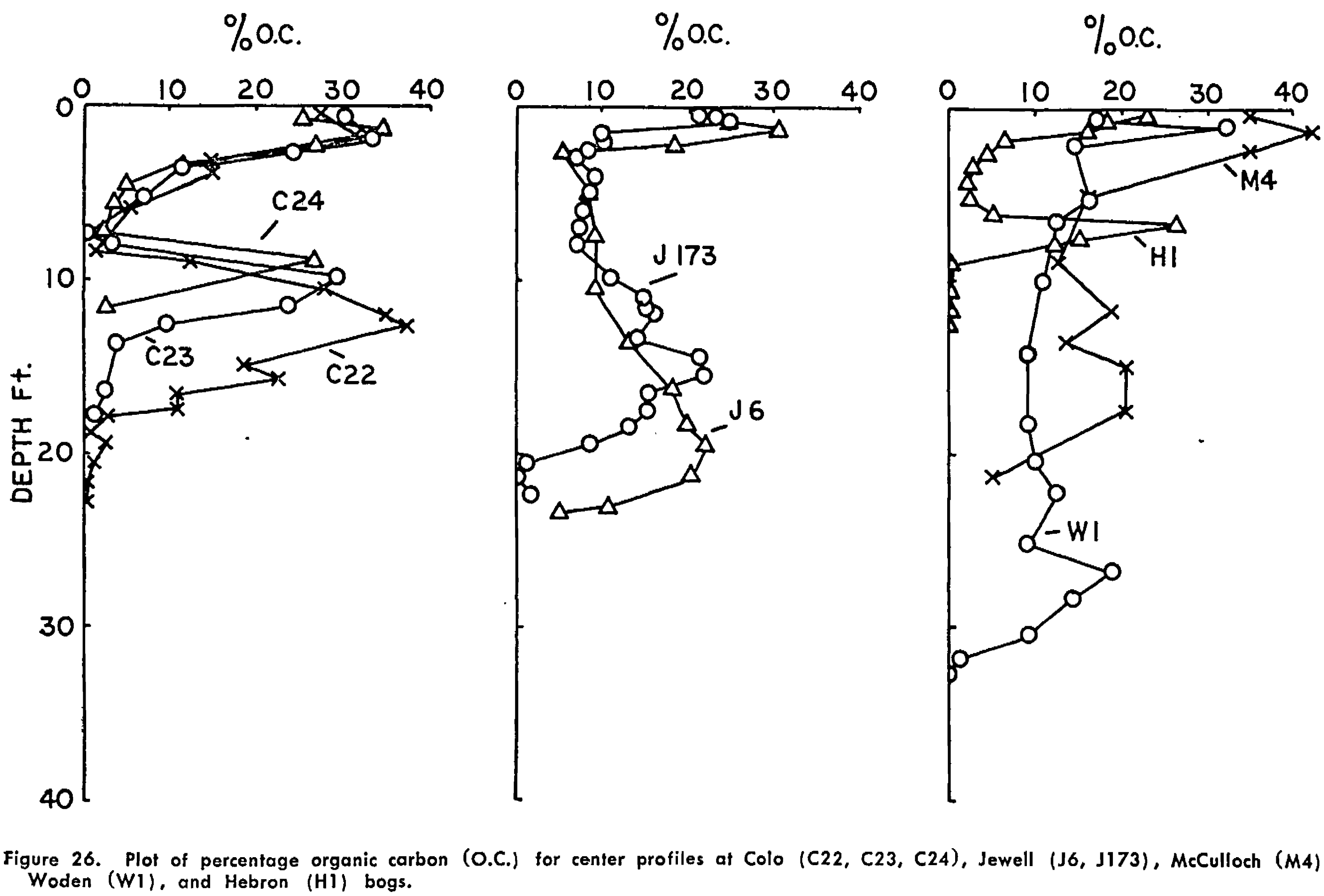


Figure 26. Plot of percentage organic carbon (O.C.) for center profiles at Colo (C22, C23, C24), Jewell (J6, J173), McCulloch (M4), Woden (W1), and Hebron (H1) bogs.

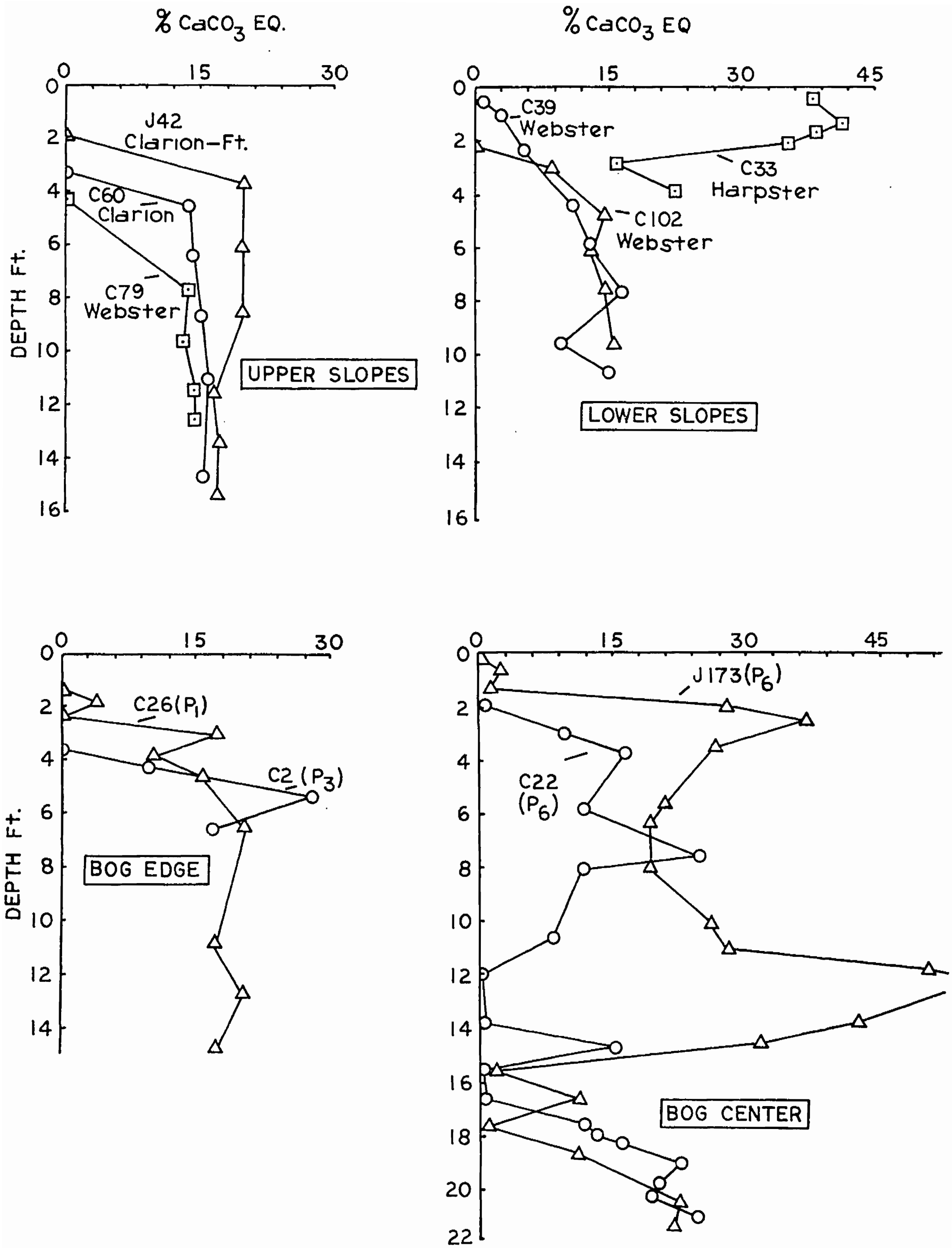


Figure 27. Plot of percentage calcium carbonate equivalent for selected profiles from the Colo and Jewell bog watersheds.

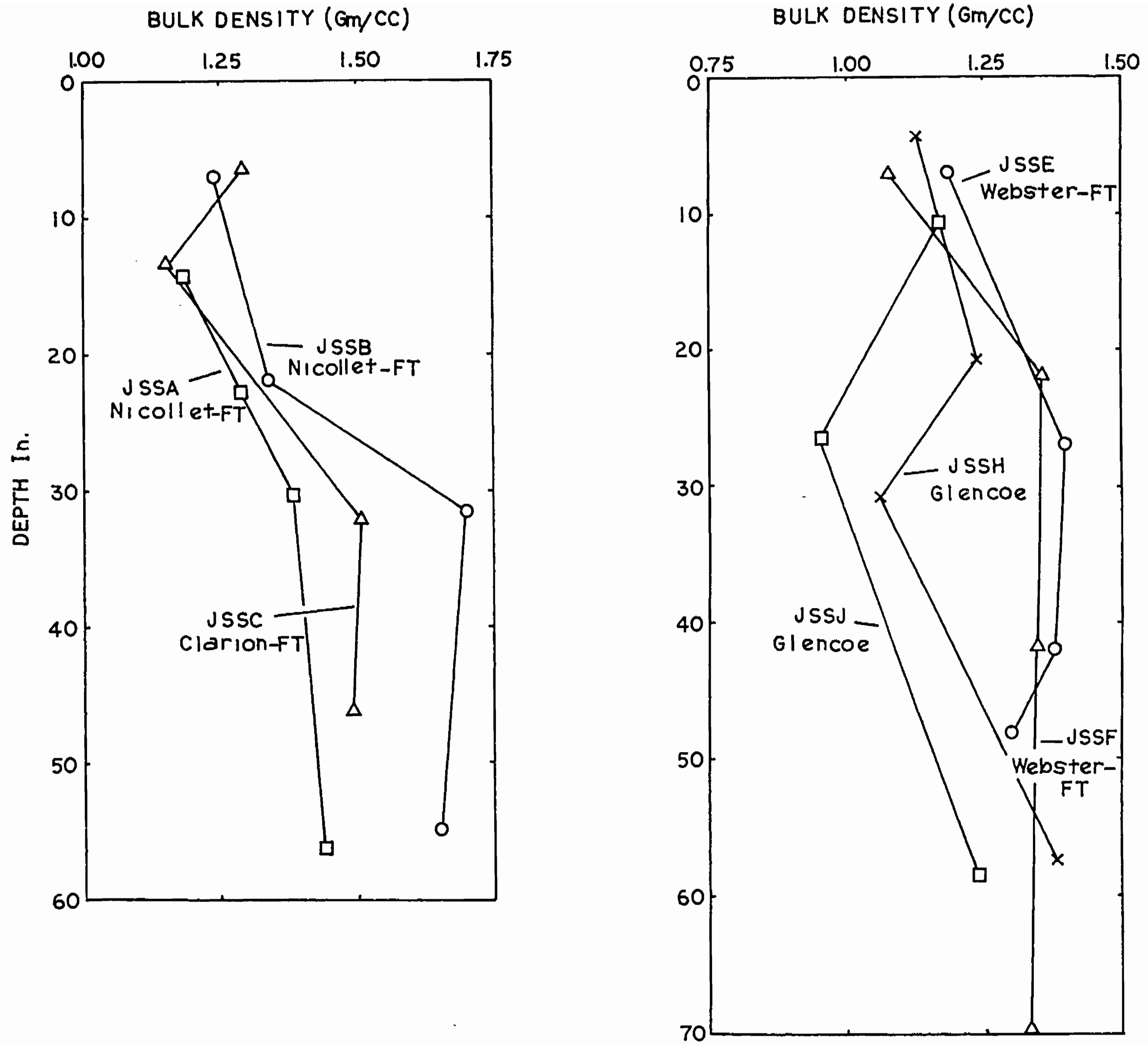


Figure 28. Plot of bulk density for selected profiles from the JSS traverse across a small enclosed depression along the perimeter of the Jewell bog watershed.

to UM zone. Herbaceous pollens continue dominant through the UM zone to the surface.

A feature of the Colo pollen diagram is the close relationship between pollen profile changes and changes in the stratigraphy. This suggests that the kind of deposition in the bog is related to the kind of vegetation within the bog watershed, although discretion must be used in direct interpretation of the vegetative cover within the watershed from the pollen data. Davis (1963) showed that conifers, in particular, tend to be over-represented in pollen diagrams because of their relatively high pollen production. Conifer pollens also may be transported up to several-hundred miles by wind and may be found in bog sediments where conifers do not grow. Consequently, the high percentage of conifer pollen at the base of the Colo bog profile may be over-representative of the conifers in the bog watershed.

However, the vegetation on the landscape may be interpreted from the pollen data, and inferences may be made about changes of the environment in central Iowa during postglacial time. Early postglacial conditions, represented by the LS sediments, were cold and inhospitable to vegetation. Progressive amelioration of the climate led to stabilization of the landscape, initially under conifers and subsequently under mixed forest species. Conditions were probably cooler at that time than anywhere in the Midwest at present and may have been comparable to present conditions in the conifer-hardwood forest areas of northern Minnesota. The change to herbaceous pollens was synchronized with the change to dark sediments of the US zone, probably relating to a rapid erosion of hillslopes in the watershed. Conditions probably became warmer and drier than the present during the interval represented by the US zone sediments, but eventually the climate became moister, and the landscape was stabilized under prairie grassland environment comparable to the present.

The pollen sequence at the Colo bog is comparable to that of the McCulloch bog published by Lane (1931), and more recent pollen studies under NSF Grant GP2610[6] indicate that pollen profiles at Jewell, McCulloch, Woden and Hebron bogs show the same general postglacial changes as the Colo profile. It, thus, seems likely that a regional postglacial-pollen sequence can be proposed that is correlated with the regional bog stratigraphy described in this report.

Plant Macrofossils

During field investigations, pieces of wood occasionally were found among the bog sediments, and a number of these were collected and identified as to genus.[7] Details of the identification of wood samples and their stratigraphic position are shown in table 8.

All wood pieces listed are from conifers, and they were found in a range of stratigraphic positions from the top of the LM zone to the contact between LS sediments and the Cary drift. The size and abundance of the samples leaves little doubt that conifers grew in the bog watersheds during early postglacial time.

Table 8. Location and identification of wood samples from bog cores.

Core[a]	Depth	Strata	Sample	Genus
C22	135 in.	Upper LM	¾ in. piece	Spruce (*Picea*)
J6	28 ft. 6 in.	Base LS	2x¾ in. piece from many	Spruce (*Picea*)
J8	22 ft. 6 in.	Base LS	2 in. piece from many	Spruce (*Picea*)
J121	126 in.	Base LS	2 in. piece from many	Spruce (*Picea*)
J198	130 in.	Base LS	1 in. piece from many	Spruce (*Picea*)
J199	102 in.	Upper LM	1 in. piece from many	Spruce (*Picea*)
Woden (W1)	30 ft. 6 in.	LS zone	2 in. piece from many	Spruce (*Picea*) or larch (*Larix*)

[a]The locations of the Colo (C) and Jewell (J) samples are given in figs. 2 and 3.

[6] Grace S. Brush, Department of Geology, Princeton University, Princeton, New Jersey, and L. H. Durkee, Department of Biology, Grinnell College, Grinnell, Iowa. [Private Communications.] 1965.

[7] Wood identification by D. W. Bensend, Forestry Department, Iowa State University.

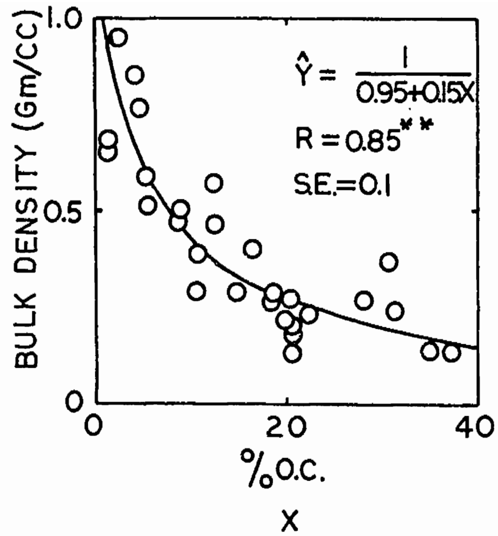


Figure 29. Plot of the relationship between percentage of organic carbon (O.C.) and bulk density for bog samples from the Colo, Jewell and McCulloch bogs. Statistical significance at the 0.01 level is indicated by **.

Radiocarbon Dates

Samples for radiocarbon dating were taken from cores in the Colo (C22), Jewell (J6, J173), McCulloch (M4) and Woden (W1) bogs. Dating was done by Isotopes Incorporated, Westwood, New Jersey, and data about each sample are given in table 9. Two sets of dates were obtained from the Jewell bog. In the first set, for profile J6, the dates for I 1017 and I 1018 were unexpectedly close. The bog core was subsequently located at J173, and the dates for samples I 1417 and I 1418 represent stratigraphic positions comparable to the two samples in J6.

Table 9. Radiocarbon dates and sample data for Colo, Jewell, McCulloch and Woden bogs.

Profile sample depth (ins.)	Horizon[a]	Isotopes number	Date B.P.
Colo C22			
34-36	Transition US-UM	I 1013	3,100±130
132-134	Upper LM	I 1014	8,320±275
186-189	Base LM	I 1015	13,775±300
Jewell J6			
24-26	Base UM	I 1016	2,365±500
210-212	Upper LM	I 1017	10,226±400
280-282	Upper LS	I 1018	10,670±400
336-342	Base LS (wood)	I 1019	11,635±400
Jewell J173			
173-180	Upper LM	I 1417	9,570±180
236-240	Upper LS	I 1418	10,640±270
McCulloch M4			
36-38	Transition US-UM	I 1412	3,170±190
135-137	Upper LM	I 1413	8,210±260
232-234	Base LM	I 1414	14,500±340
Woden W1			
266-269	Lower US	I 1415	7,050±210
379-384	LS zone	I 1416	11,570±330

[a]Dated materials are sediment or muck unless otherwise specified.

The basal dates at Colo and McCulloch bogs of 13,775 and 14,500 years, respectively, approach the Cary age published by Ruhe and Scholtes (1959, p. 592). Dates from near the top of the upper muck zone of 8,320 years at the Colo bog and 8,210 years at the McCulloch bog agree with the dates of 8,170 and 8,110 years for a comparable stratigraphic position in the McCulloch profile, published by Ruhe et al. (1957, p. 687). Dates for the transition from upper silt zone to upper muck zone of 3,100 years at Colo and 3,170 years at McCulloch bog agree closely, but are somewhat older than the Jewell bog date of

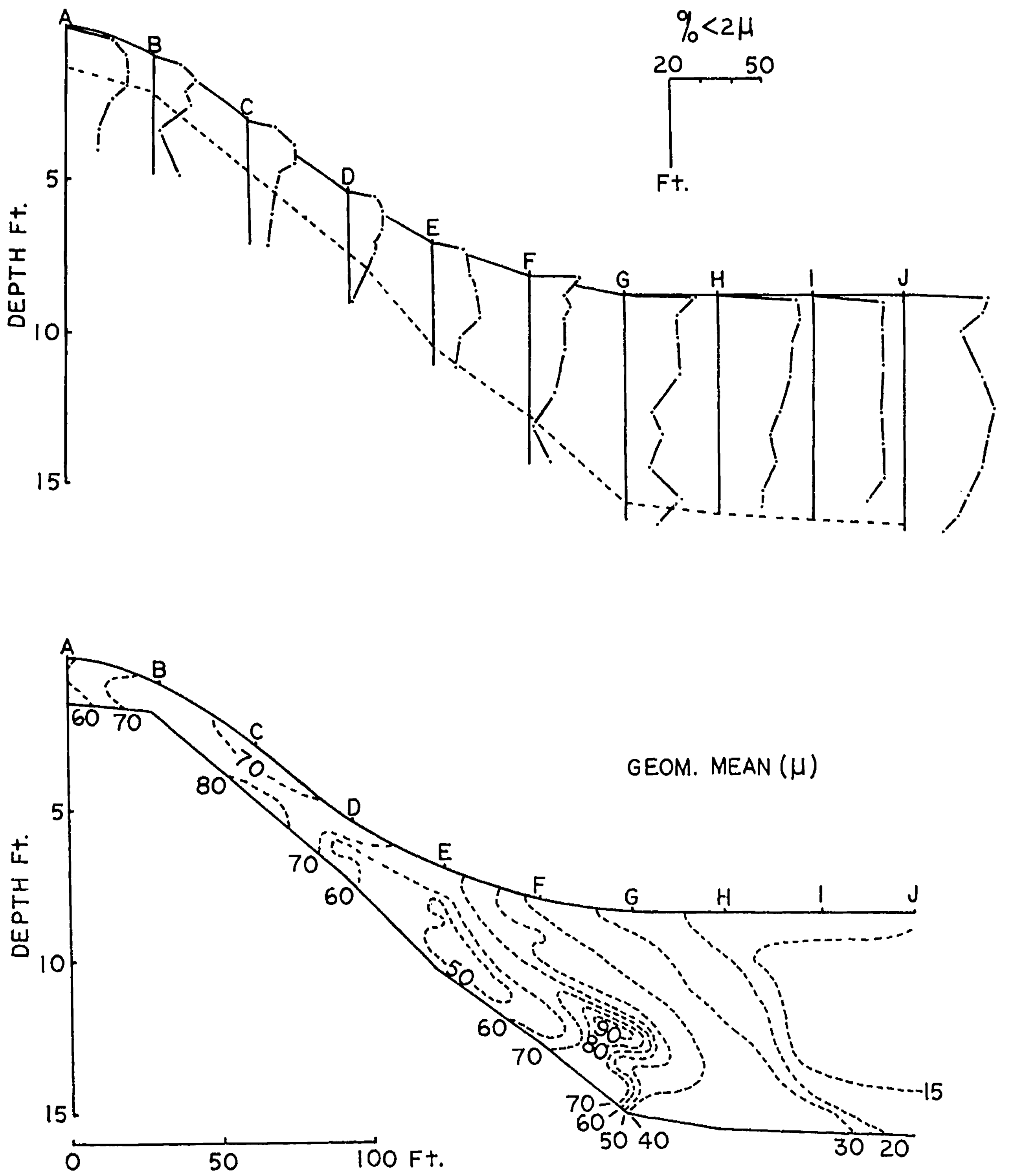


Figure 30. Plot of particle-size parameters for the surficial sediments of the JSS traverse along the perimeter of the Jewell bog watershed.

2,365 years for the same stratigraphic position.

The basal dates of the Jewell and Woden profiles of 11,635 and 11,570 years, respectively, agree with dates for the beginning of the post-Cary interval, published by Ruhe and Scholtes (1959, p. 592), but are somewhat younger than the basal Colo and McCulloch bog dates of table 9. Only one date, basal McCulloch, is inconsistent with dates for the Algona moraine outwash and the framework of dates for Iowa, published by Ruhe and Scholtes (1959, p. 592).

The dates at the Jewell bog of 10,670 (J6) and 10,640 (J173) years represent the stratigraphic tran-

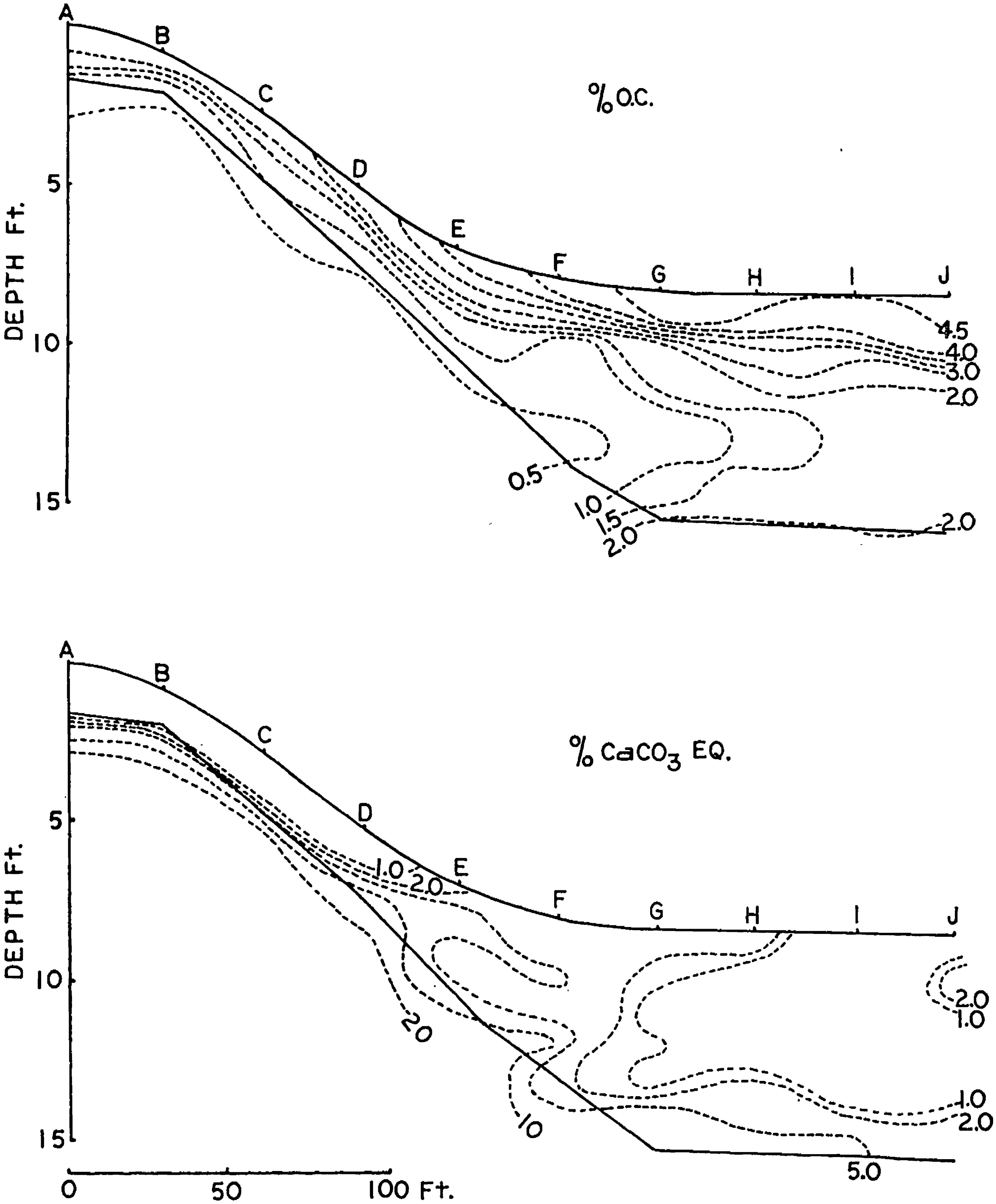


Figure 31. Contoured plot of organic-carbon and calcium-carbonate equivalent data for soils along the JSS traverse in the Jewell study area.

sition from the lower silt zone to the lower muck zone. There is general agreement among the samples for a date of 8,000 years for the transition from lower muck zone to upper silt zone. The dates from this stratigraphic position at the Colo and McCulloch bogs are close to this value, and the dates of 7,050 years at the Woden bog and 9,570 years at the Jewell bog (J173) are positions in the profile from which dates close to 8,000 years could be interpolated for the transition.

The stratigraphic position of dated samples and the dates are given in fig. 33 for Colo, Jewell, McCulloch and Woden bog profiles. This figure provides the data from which the following dates were determined for the important stratigraphic positions in bog profiles of the Des Moines lobe in Iowa:

Transition UM/US	3,000 years ago
Transition US/LM	8,000 years ago
Transition LM/LS	10,500 years ago
Transition LS/Cary	13,000 years ago

The date for the transition LM/LS is rounded to 10,500 years and is, thus, slightly different from the 10,000 to 11,000 year range discussed for this transition by Walker (1965).

Bog Sedimentation and Slope Reduction

In an earlier section of this report, it was shown that distinct units of surficial sediment occur within the Colo and Jewell watersheds. If the surficial sediment in lower slope and bog units has originated from the area of upper slopes, represented by unit A, values of surficial erosion can be determined from the sediment volume data in tables 4 and 5. A first step in the calculations is to correct bog sediment volumes for bulk density so that they can be directly related to drift-derived soil; for example, A horizon material of bulk density 1.2 gm/cc. Bog strata are corrected for density on the basis of the average bulk density of silty mineral sediments 0.6 gm/cc and the average bulk density of muck zones of 0.2 gm/cc. If it is assumed that all the bog sediments are derived from the area of sedimentary unit A and that no substantial change in density occurs across the area occupied by sedimentary unit B, the calculations of equivalent A horizon thickness for surficial and bog sediments at Colo can be made as shown in table 10. These data are then rearranged to represent the equivalent thickness of each stratum in the bog sequence in table 11. Similar calculations were made for the Jewell bog, and these are presented in tables 12 and 13.

The tabulated data show that there has been a significant modification of the landscape during post-Cary time, especially in the Jewell watershed where slopes are steeper. The largest amount of erosion in area A of both watersheds took place during the interval represented by the US zone, and the smallest amounts of erosion occurred during the intervals represented by the muck zones.

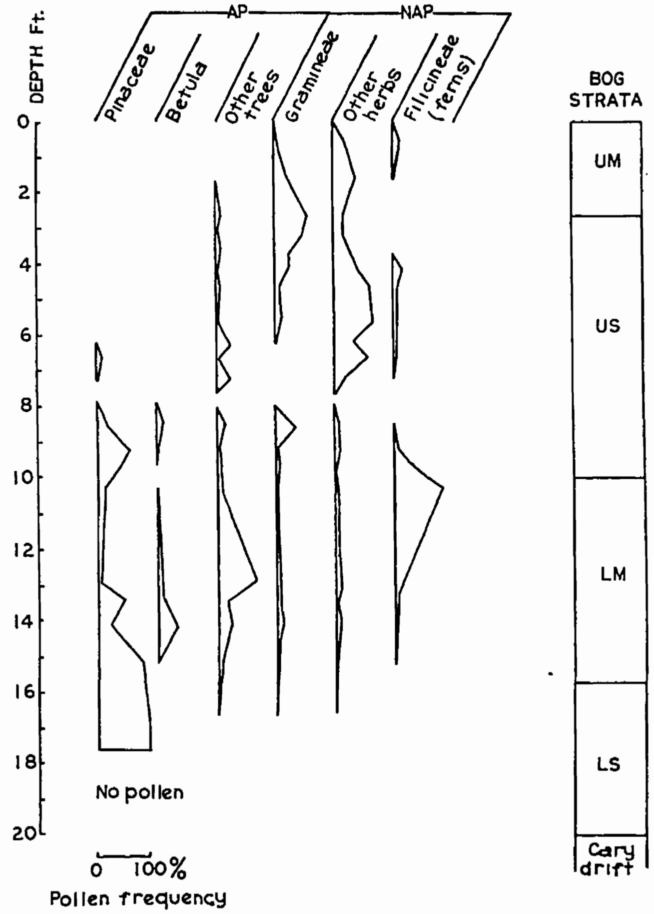


Figure 32. Pollen and stratigraphic profiles for the Colo bog.

Table 10. Conversion of bog sediment volumes to soil A horizon equivalent in the Colo bog watershed.

Sed. unit	Area (square miles)	Stratum equivalent	Equivalent stratum thickness (ft.)	Thickness corr. for density (ft.)	Product, Area X thickness
B	0.030	US	3.5	3.5	0.105
D1	0.028	UM	2.0	0.4	0.011
		US	1.5	0.8	0.022
		LS	4.0	2.0	0.056
D2	0.003	UM	3	0.6	0.002
		LM	2	0.4	0.001
		US	5	2.5	0.008
		LS	5	2.5	0.008
D3	0.001	UM	3	0.6	0.001
		LM	5	1.0	0.001
		US	10	5.0	0.005
		LS	7	3.5	0.004
				Sum	= 0.224
				Av. thickness as A hor.	= 2.8 ft.

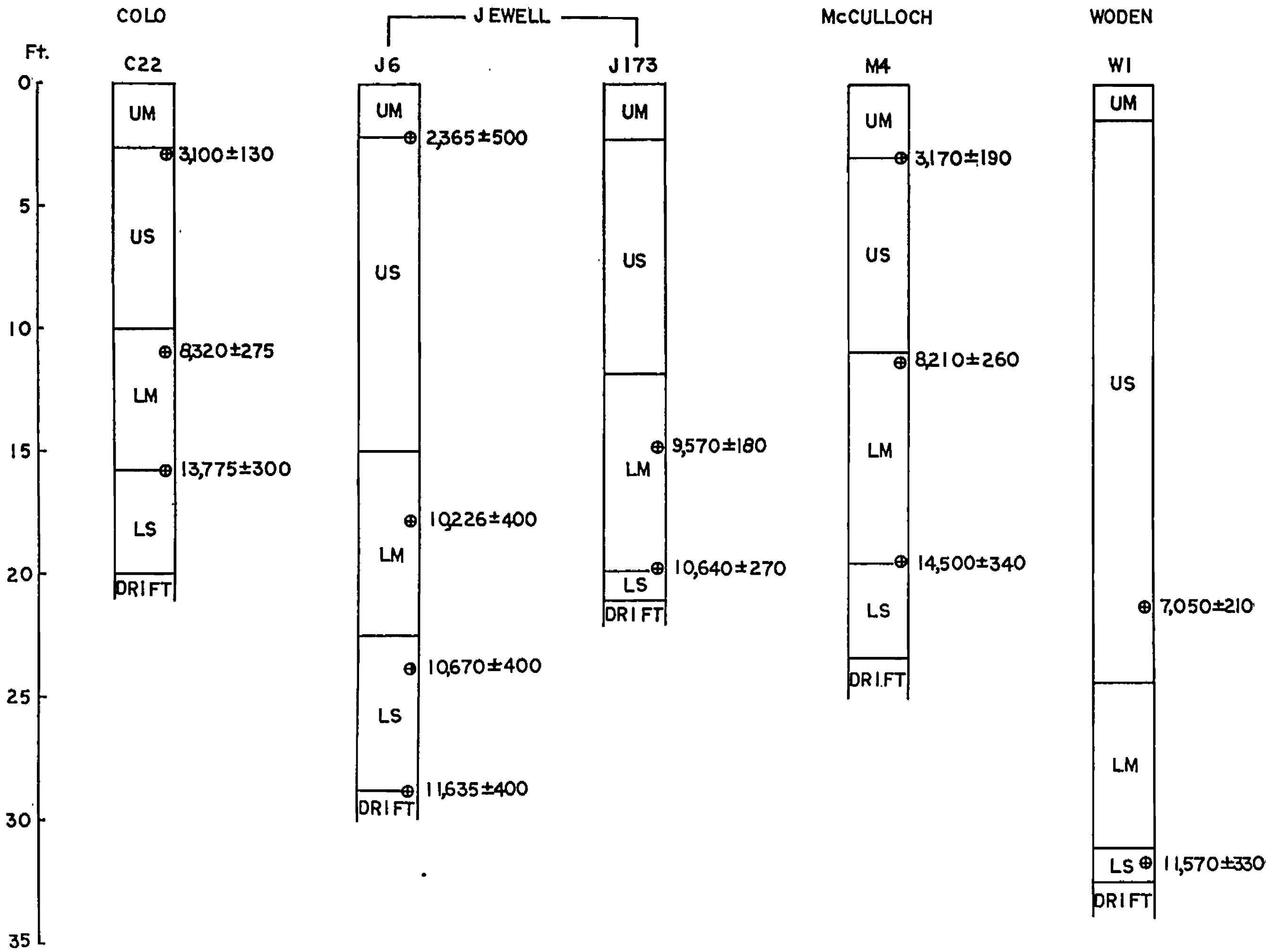


Figure 33. Radiocarbon dates and stratigraphy for the center profiles at Colo, Jewell, McCulloch and Woden bogs.

Table 11. Soil A horizon equivalent thickness of bog strata at Colo.

Stratum	Equivalent A horizon thickness (ft.)
UM	0.2
US	1.7
LM	0.03
LS	0.9
Total	2.8

Table 12. Conversion of bog sediment volumes to soil A horizon equivalent in the Jewell bog watershed.

Sed. unit	Area (square miles)	Stratum equivalent	Equivalent stratum thickness (ft.)	Thickness corr. for density (ft.)	Product, Area X thickness
B	0.098	US	3.5	3.5	0.340
C	0.006	US	1.25	1.25	0.075
		LS	1.25	0.6	0.004
D1	0.028	UM	1	0.2	0.006
		US	4	2.0	0.056
		LS	1.5	0.8	0.022
D2	0.041	UM	2	0.4	0.016
		LM	5	1.0	0.041
		US	6	3.0	0.123
		LS	2	1.0	0.041
D3	0.026	UM	2	0.4	0.010
		LM	6	1.2	0.031
		US	15	7.5	0.195
		LS	2	1.0	0.026
				Sum	= 0.986
			Av. thickness as A hor.		= 6.6 ft.

Table 13. Soil A horizon equivalent thickness of bog strata at Jewell.

Stratum	Equivalent A horizon thickness (ft.)
UM	0.2
US	5.3
LM	0.5
LS	0.6
Total	6.6

The rates of hillslope erosion and bog deposition can be calculated from the data of tables 11 and 13 and the radiocarbon dates listed in table 9. The accumulation rates for bog sediments are listed in table 14, and the hillside erosion rates are listed in table 15. The rates of bog accumulation of 2.2 to 15.2 cm/100 yrs. are comparable to those calculated by Durno (1961, p. 350) for moss-rich peats ranging from 1.2 to 11.1 cm/100 yrs. Mattson and Koutler-Andersson (1954, p. 361) calculated rates of accumulation ranging from 3.4 to 6.9 cm/100 yrs. for peat deposits dating from 4,000 years ago to the present. These rates are somewhat higher than rates for the UM zone of comparable age. Apart from the LM zone of the Jewell bog, the data show that the US zone sediments accumulated more quickly than the muck zone sediments.

Table 14. Accumulation rates for bog center profiles.

Stratum	Colo bog in./100 yr.	Jewell bog in./100 yr.	McCulloch bog in./100 yr.
UM (organic)	1.13	1.06	1.16
US (mineral)	1.89	2.10	1.98
LM (organic)	1.06	6.00	1.54
LS (mineral)		1.30	
Total	1.45	2.16	

Table 15. Hillside erosion rates for Colo and Jewell watersheds in terms of A horizon equivalent.

	Colo		Jewell	
Stratum	in./1000 yr.	tons/acre/yr.	in./1000 yr.	tons/acre/yr.
UM (organic)	0.72	0.1	1.08	0.2
US (mineral)	4.08	0.7	8.76	1.5
LM (organic)	0.07	0.01	6.00	1.0
LS (mineral)	5.4	0.9	7.20	1.2
Total	2.58	0.5	6.60	1.1

Erosion data in table 15 show that the highest rates of removal from hillslopes occurred during the interval represented by the US zone. The rates represented by the muck zones are smaller than the rates of the mineral sediment zones in each bog. The high erosional rates for the Jewell bog are less than the rates of 5 to 59 tons per acre annually, published by Bennett (1939, p. 162), for corn and fallow on Marshall silt loam of 9-percent slope in western Iowa. The bog watershed rates are comparable, however, to the lowest rates of presettlement erosion of 6 to 44 inches per 1,000 years, calculated for loess landscapes of southwestern Iowa by Ruhe and Daniels (1965).

Soils and the Historical-Environmental Framework

A chronology of vegetation, landscape and climate is presented in table 16, with the significant radiocarbon dates rounded to the nearest 500 years. The primary basis for subdivisions of the postglacial interval is sedimentary data rather than vegetative data. This approach differs from recent work by Wright (1964, p. 636) who proposed that the sequence of main Wisconsin glacial phases in Minnesota should terminate with the replacement of spruce forest shortly after the Valders maximum of 10,500 BP. By contrast, the decision as to the stratigraphic position of the end of the Cary glaciation in the bog watersheds of the present study rests on the clear demarcation between the coarse Cary till sediments and the fine-textured lower silt zone of the bog sediments. The boundary between these sediments can be readily identified in the field, and the lower silt zone can be traced laterally from the bog center position to the base of adjacent hillslopes.

Table 16. Outline of the historical-environmental framework for soils and landscapes of the Cary drift, Iowa.

Substage	Stratigraphic zone	Environment	Rate of hillside erosion, Colo bog (tons/acre/yr.)	Date (yrs. ago)
Recent (Post-Cary)	Upper muck (UM)	Present		
				Modern
		Oak invading, prairie subclimax	0.1	
				3,000
	Upper silt (US)	Prairie (warm, dry herbaceous maximum)	0.7	
				8,000
	Lower muck (LM)	Hardwood forest, birch (warming) Conifers, spruce	0.01	
				10,500
	Lower silt (LS)	Conifers (cool)	0.9	
				13,000
Cary		Glacial		

The first post-Cary interval from 13,000 to 10,500 BP represents the initial erosion of the Cary drift surface. The low organic-matter and pollen content of the sediments in the LS bog zone indicates that the vegetative cover on hillslopes was meager, favoring the more rapid erosion that has been calculated for this interval. Pollen indicate that the initial postglacial vegetation was dominated by conifers There is no evidence in the pollen profiles of early postglacial tundra with a high proportion of nonarboreal species such as that described by Martin (1958, p. 494) in the eastern United States. The stratigraphic transition from LS zone to UM zone represents a change in erosional conditions on the hillslopes of the bog watersheds. The reduced erosion rate suggests that the landscape became stabilized under forest that, between 10,500 and 8,000 years ago, changed from conifers to mixed forest with hardwood species prominent.

During the interval represented by the US bog zone from 8,000 to 3,000 years ago, the vegetation and landscape underwent considerable change. The average amount of hillslope reduction during this period was equivalent to the thickness of the upper solum of soils presently occurring on the Cary drift. This amount of erosion was sufficient to remove most of the soil developed prior to 8,000 years ago on the upper hillslopes. The condition of the hillslope surfaces at this time favored soil removal and probably resulted from a relatively sudden change in climate, causing depletion of the existing vegetative cover and exposure of the soil surface. It is noteworthy that the flora, such as the *Chenopodiineae*, during the early part of this interval indicate somewhat drier conditions than the present, perhaps comparable to the climate proposed for the postglacial hypsithermal by Deevey and Flint (1957). The appearance of grasses in the Colo pollen diagram (fig. 32) is associated with restabilization of the bog watershed surfaces at 3,000 years ago and greatly reduced rates of hillslope erosion that have continued to the time of settlement.

Since the bog watersheds contain large proportions of post-Cary surficial sediment stratigraphically equivalent to the US zone of the bogs, the soil landscapes generally must be younger than 8,000 years, and most of the soil features relating to the prairie environment have been developed during the last 3,000 years of relative erosional stability. Thus, soils such as Clarion, Nicollet, Webster and Glencoe truly formed in a prairie environment. Although pollen-stratigraphy indicates that forest occupied parts of the landscape during early postglacial time, no clear evidence of forest influence was observed in the soils. Numerous undisturbed soil cores were examined to determine whether some morphological feature occurred, such as gray coatings on ped surfaces (= silans), which would indicate prior forest influence (Arnold 1963, p. 94-97). Only 2 profiles from 43 sampled across various parts of the landscape showed any sign of these features; and in these two profiles, the expression of gray ped surfaces was minimal.

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